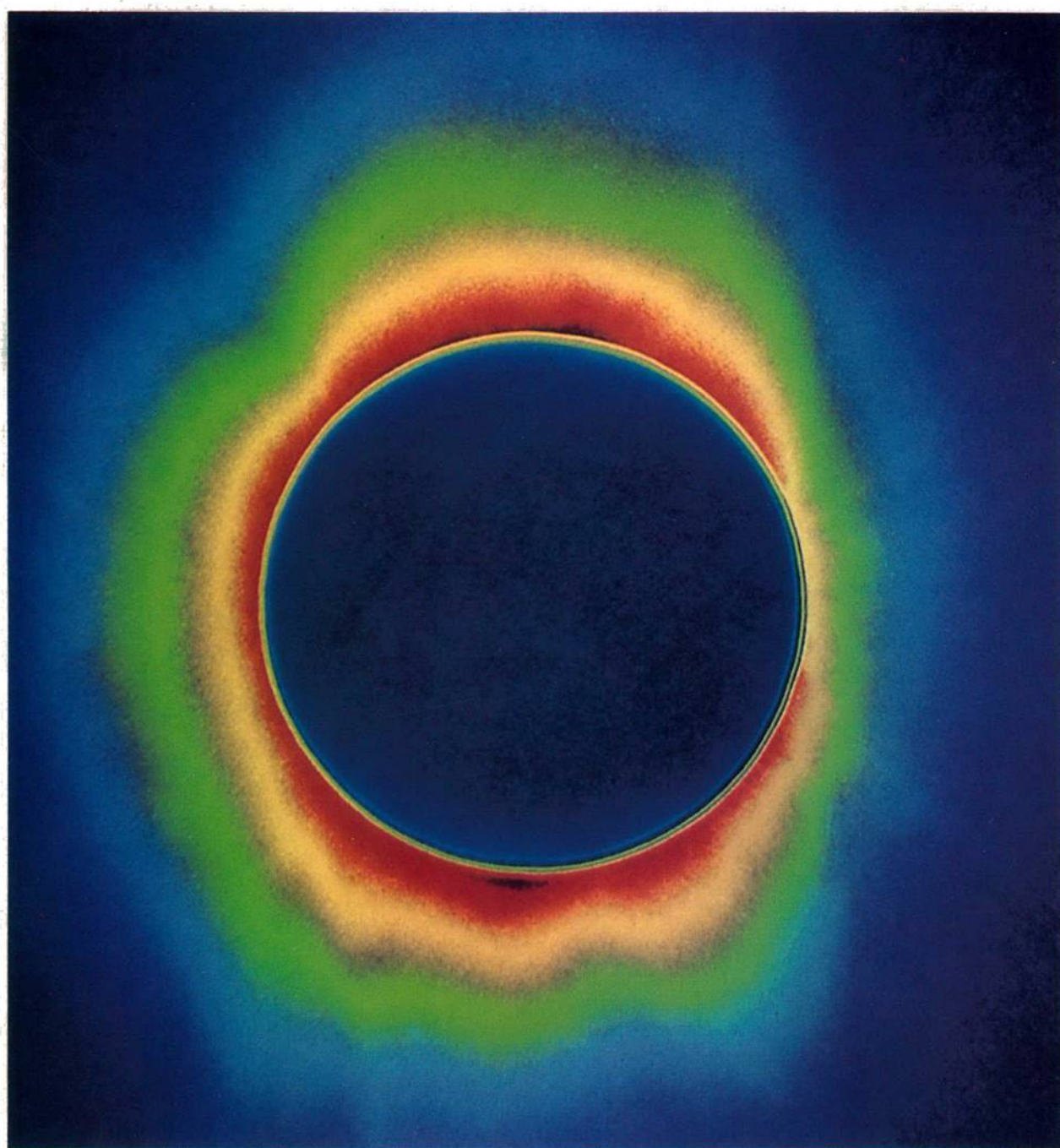


ASTRONOMY

SEPTEMBER 1977

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Jupiter From Io

This dramatic painting reveals an incredible vista that man may never witness first hand: the incredible bulk of Jupiter looming over the surface of its satellite Io. Located deep within Jupiter's intense magnetic field, Io is one of the most lethal places in the entire solar system. To view this scene, we must rely on the imagination of artist John Clark.

To you, our readers, **ASTRONOMY** now offers a series of 8 dynamic, new, full color Art Reprints of some of the best paintings — by artists John Clark, Victor Costanzo, James Hervat, Mark Paternostro, Adolf Schaller and Rick Sternbach — that have appeared in **ASTRONOMY Magazine**.

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A nearly invisible small black hole speeds through a dense interstellar cloud of gas and dust, leaving behind a trail of gravitationally disturbed material. The infalling material becomes hot and emits light as it drains out of the known universe. Artist Mark Paternostro speculates on the appearance of these still undetected objects.



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The Galactic Core

The nucleus of our galaxy is one of the true unknowns in our universe. Recent radio and infrared observations suggest that two titanic swirling rings of gas and dust occupy the core of our galaxy. These rings were apparently produced by an explosion 10 million years ago. Victor Costanzo's painting indicates that actual conditions at the galaxy's center remain a mystery.



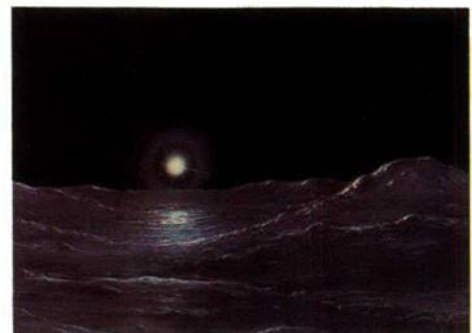
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Colony in Space

What will space stations and orbiting colonies of the future look like? Artist Rick Sternbach provides an ingenious answer in his painting of a mile wide space station wheeling slowly above the gibbous Earth. Shuttle rockets near the station's hub bring ore from the lunar surface for refinement in the station's zero gravity manufacturing center.

Pluto

The setting sun glints off a low plain of methane ice on the surface of the smallest and most distant planet, Pluto. The cold and forbidding scene — completely alien to Earth dwellers — comes to life in this rendition by James Hervat. The mysteries of Pluto are brought home to us as we stand and gaze back toward our incredibly distant sun.



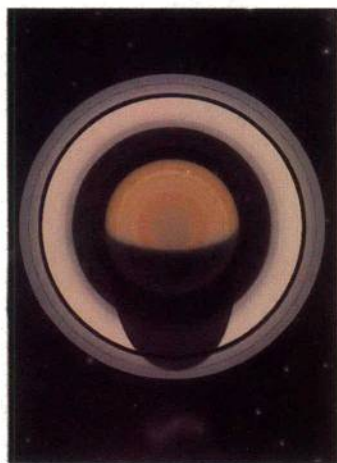
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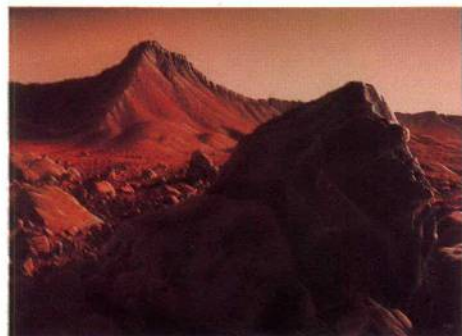
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Saturn

In an unusual perspective from above the north pole of Saturn, we can identify the planet's three main rings and their sizes relative to Saturn itself, enabling us to grasp the vast extent of Saturn's ring system. This remarkable painting by Adolf Schaller gives us a view of the planet not obtainable from Earth.

Vallis Marineris

Photographs returned from Mariner and Viking probes revealed for the first time the immensity of Vallis Marineris, the equatorial canyon of Mars. This painting by Adolf Schaller — meticulously transcribed from overhead Viking photos — takes us to the foot of a blanket of landslide rubble in the canyon itself.



Actual Size: 17" x 22"



Actual Size: 17" x 22"

Space Telescope

Painted by John Clark from official NASA blueprints, this poster depicts the Space Telescope — a powerful 94 inch (2.4 meter) aperture telescope due to be launched during the early 1980s by NASA's Space Shuttle. This is an accurate depiction of an instrument that will revolutionize man's view of the universe during the decades it remains in operation.

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PUBLISHER'S MEMO

Greetings and Salutations, Folks.

Once upon a dismal dreary, 48 months ago in memory weary, when the world was weekly boring — dull and freaky, but for promise of a brightly glimmering luminary that would surely bring surcease to gloom with exciting drama as the World's Most Beautiful Astronomy Magazine.

Yes, distinctly I recall it was in that early fall, and each separate color 16 print form wound its way through fold and staple all.

And the throbbing deep undaunted drumming of each ink font cylinder ballooned in unison to a deafening din that filled me — and as the crescendo reached its peak, became the beating of my heart that thrilled me with such terror till I screamed above the pressroom din, "This is still only issue two."

And now, today in pressroom standing while I ponder always wondering, never doubting, and still dreaming dreams of world unseen until I'm loudly screaming above the beating drumming of my heart, "This Golden issue 50th is still too few!!!" Well folks, that was my one attempt at poetry — an attempt which I fear may set back the art form several thousand years. A poet I'm not — a bit prosey at times, maybe. But not a poet.

Anyway, this September 1977 issue of ASTRONOMY magazine marks our 50th issue anniversary and even though it is not our 50th year of service to you — it certainly is ASTRONOMY magazine's golden anniversary of monthly publication. Our greatest pride in celebrating this issue is that it represents 50 consecutive issues of ASTRONOMY published without interruption since August 1973.

Switching gears for a moment, Penny Oldenburger and I have worked on ASTRONOMY from the very beginning, and as my Publisher's Memos grew more and more slaphappy, Penny has simply been aching for the chance to

write a Publisher's Memo for me. So it seems appropriate to give her that much-longed-for opportunity in this issue.

This is where I hang up my quill to dry for September, and I now turn over to Penny her heart's desire — to finish my Publisher's Memo. Sure hope I live through this!! If I do . . . snicker . . . snicker, I'll be back next month.

With warm regards,



Stephen A. Walther
Publisher

Heellpp!! This is a little like being the kid in the candy store — wanting to buy everything, but having only a quarter. There's a lot to say — this being my "golden opportunity" — but not enough space.

To wax sentimental for a moment — sorry, but I've got to get even while I can — on behalf of the entire ASTRONOMY staff, I'd like to say: "Thank you, Steve . . . for giving us a chance to help you realize your dream. By sharing it intimately with us, it's become our dream too." (. . . and sometimes a nightmare, and . . .)

It's been a fascinating and exciting 4-1/2 years — and how we've grown! From three full time staff members, we've grown to 15; from a magazine of 48 pages to 80; from an old beauty shop with one card table and two chairs (for three people!) to a real office-type office. But most rewarding is the fact that we're now serving five times as many subscribers as we did with our first issue. Your support, suggestions and comments will never cease to be valuable to us.

There have been some interesting developments on the home front:

1) ASTRONOMY's newsstand sales are now being channeled through Eastern News Distributors, Inc. So if your local bookstores or newsstands are interested in selling ASTRONOMY, have them contact Eastern at 111 Eighth Ave., New York, N.Y. 10011. (We will continue to handle bulk sales to planetariums, museums, libraries and astronomy clubs.)

2) Hughes Airwest has added ASTRONOMY to its in-flight library of reading materials! If you travel frequently and would like to see ASTRONOMY on the airlines you use, let us — or your airline representatives — know.

By the way, we have a favor to ask of you. In our never-ending efforts to combat inflation, we're undertaking an experiment. We've decided to try mailing ASTRONOMY with a different type of wrapper: It will be bound to the magazine like an extra cover, but should be easily removable. Starting with this issue and continuing for several months, we'll be sending ASTRONOMY with this type of wrapper to several thousand of our subscribers (randomly selected, of course!) throughout the country. The rest of you will continue to receive your magazines in envelopes.

But back to the favor: We'd like to hear from those of you who receive magazines in the new wrapper. Let us know if you continue to receive your issues on time, and — more importantly — what condition they arrive in after being subjected to postal ravages.

Yipes! Steve's back already — and he's threatening to pull the plug on my typewriter!

Till our 100th issue . . .

Silently yours,



Penny Oldenburger
Managing Editor

ASTRONOMY

The World's Most Beautiful Astronomy Magazine

September 1977

Vol. 5, No. 9

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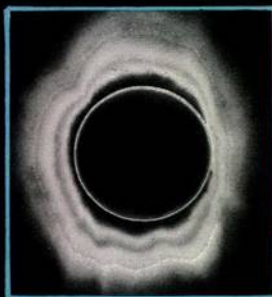
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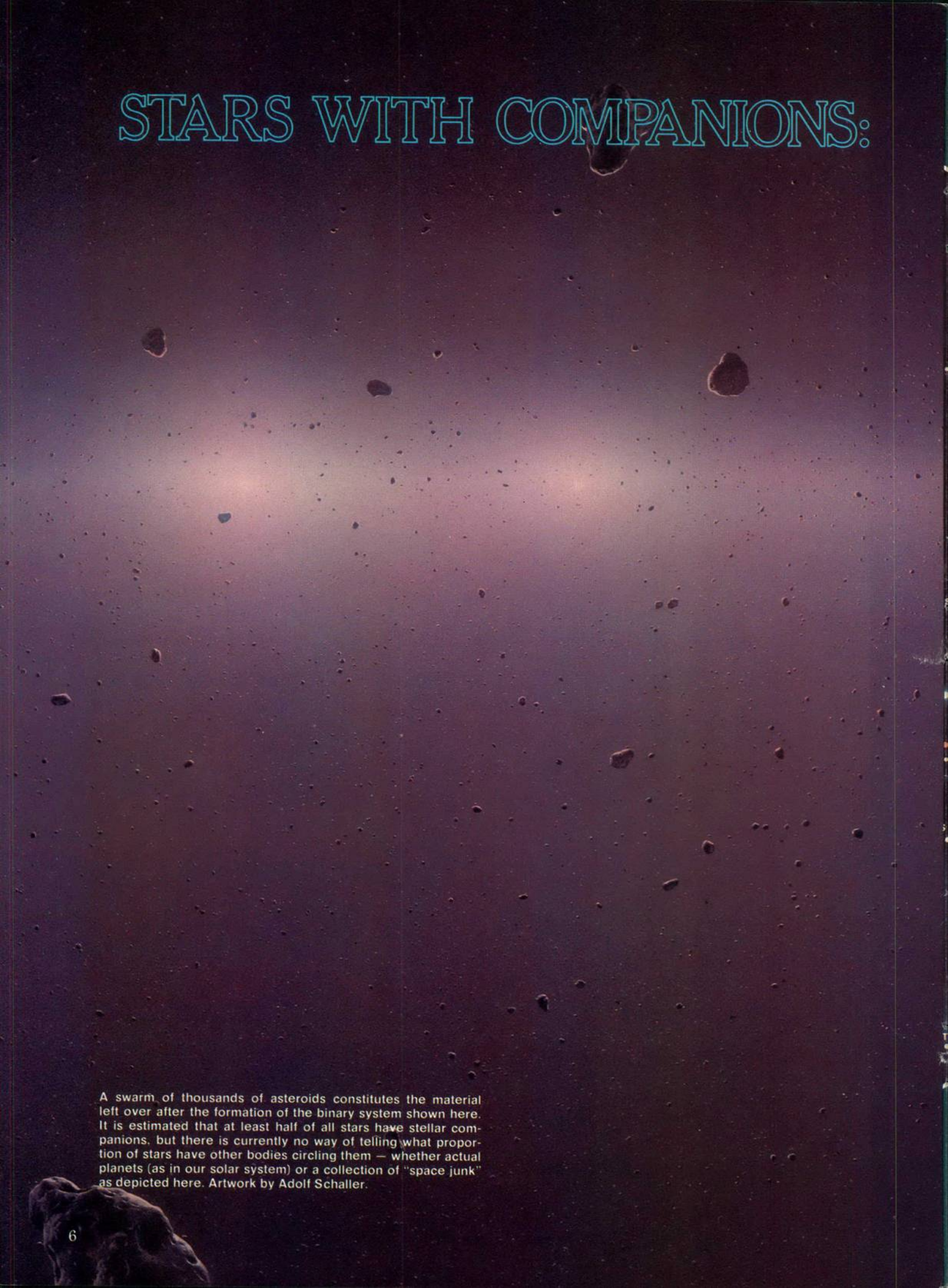


Cover

Our sun, pictured on the cover, is not a single star, but a star with companions — the planets. More than half of the stars we see in the sky also have companions: another normal star, a tiny superdense white dwarf companion, a very massive planet unlike any in our solar system or, like our sun, a collection of tiny cool planets. This month's lead feature explores stellar companions, what we know of them, and how many are really out there in space. ASTRONOMY also takes a look at the semi-intelligent robot explorers we must build to reconnoiter hostile planetary environments before man can set foot on these alien worlds. We'll also fill you in on photography with your Newtonian reflector, mountings for home built telescopes, and the scourge of the sky observer — light pollution. Solar corona isophoto of the 1973 solar eclipse by Fred Espenak.

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STARS WITH COMPANIONS:

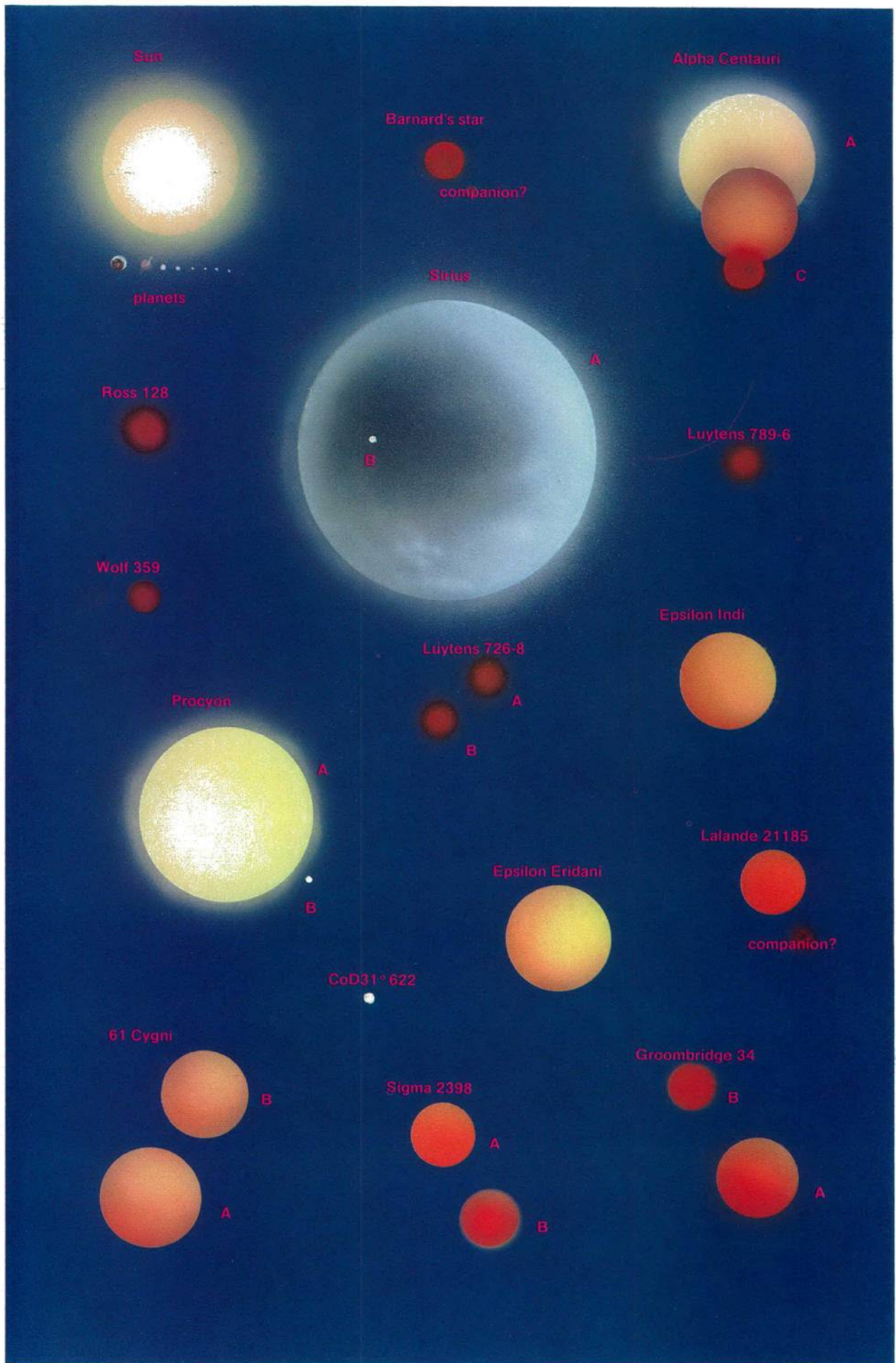


A swarm of thousands of asteroids constitutes the material left over after the formation of the binary system shown here. It is estimated that at least half of all stars have stellar companions, but there is currently no way of telling what proportion of stars have other bodies circling them — whether actual planets (as in our solar system) or a collection of "space junk" as depicted here. Artwork by Adolf Schaller.

MORE THAN MEETS THE EYE

by
William K. Hartmann





Many of us are under the impression that nearly all stars are solitary wanderers through space. When we look into the sky, we see them scattered apparently one by one, and a casual survey with a telescope seems to reveal that there is only a small fraction of stars with binary companions. Traditional astronomy books (and even some astrophysicists) therefore discuss stars with companions as if they were peculiar rarities.

Recent work is changing these preconceptions; in fact, most stars are *not* single. Stars with planetary companions and stars with stellar companions may even be different end results of the same basic formation process.

We obtain our best statistics from the closest stars to the solar system, because these are the most easily visible. If we investigate all the known nearby systems, we quickly find that most of them are *not* single. (There's a good reason to claim that this "local group" is a representative sample of all the stars in our galaxy's disk, because the disk's stars have been well mixed during the 50 or so trips they've made around the nucleus since the galaxy formed.) What statistics on stellar companions can we record from such an investigation? We can discover the masses of stars relative to the sun and we can record the orbits of stellar companions in terms of their separation distances in astronomical units (Earth's separation from the sun equals one astronomical unit).

We begin our survey with the nearest star, our sun. The sun has a mass which is written as $1M_{\odot}$. Is the sun single? Certainly not. Its most obvious companion, from the viewpoint of a stellar astronaut, is an object with mass $0.001 M_{\odot}$ — Jupiter. Jupiter isn't a true star because it doesn't have enough mass to generate central pressures, or temperatures, to create nuclear reactions. It would need about 80 times more mass than it has to do that. It does, however, emit more energy from its own slow contraction that it receives from the sun, and it might be called an "almost-star" that never quite made it.

After we leave the solar system, the next nearest star system is also multiple — that of Alpha Centauri (about 4.4 light-years away). The brightest star in that system is Alpha Centauri A, a sun-like star with a mass of $1.1 M_{\odot}$. Orbiting about 24 A.U. from it is another sunlike star with a mass of $0.9 M_{\odot}$ (Alpha Centauri B). Orbiting around that double system at a distance of some 10,000 A.U. is a small star called Proxima Centauri, with

a mass of only $0.1 M_{\odot}$. If any of these stars has a Jupiter sized companion, it would be very difficult to detect because of its faintness and small mass. We thus meet our first limitation in the companions we can detect even among the nearest stars.

The next nearest star is a recently discovered object cataloged as CoD31°622. It is believed to be a dwarf type star about 4.4 light-years away, and no companions are known. Therefore, among the three nearest systems, we statistically have about two-thirds with companions.

The next stop on our reconnaissance would be Barnard's star, whose mass is unmeasured but is probably about $0.2 M_{\odot}$ — about twice the mass of Jupiter. One model places these two objects a little over 1 A.U. apart, thus somewhat resembling our solar system. There have, however, been conflicting analyses. Some models include several secondary planetlike objects, while another analysis may find no evidence at all of a companion. We will assume there is at least one companion, and list 75 percent of the star systems out to six light-years as having companions.

At a distance of 7.6 light-years is the small star Wolf 359, with mass only about $0.1 M_{\odot}$ and no known companion. At 8.1 light-years is a binary system, +36°2147, consisting of two small stars of mass $0.35 M_{\odot}$ and $0.02 M_{\odot}$. These two are reported circling each other at a separation of only 0.07 A.U. Next, at 8.6 light-years, is the brilliant star Sirius, with $2.3 M_{\odot}$. Its famous companion is the first discovered white dwarf, with a mass of $1 M_{\odot}$ and a separation about 20 A.U. At 8.9 light-years comes still another binary pair — L 726-8. This consists of two small stars of about $0.044 M_{\odot}$ and $0.035 M_{\odot}$ separated by about 11 A.U. At 9.4 light-years is Ross 154, a star of roughly $0.4 M_{\odot}$ and no known companion.

Thus, within a distance of 10 light-years, the statistics of our reconnaissance show at least 14 full-fledged stars organized into nine systems, of which about two-thirds are binary or multiple.

If we continue our search out to a distance of 13 light-years (four parsecs), we pick up a total of some 36 stars arranged in 25 systems, but the fraction known to be either binary or multiple drops to about half. To put it another way, the farther away we point our telescopes, the fewer companions we can see.

Nonetheless, in order to understand the origin of binary stars and any possible connection with the origin of planetary systems, we must at least know the statistics of systems with one member, two members, and so on. Table 1 on page 14 shows the state of our knowledge. Astronomer A.H. Batten, in his 1973 book on binary stars, summarized a

The stars in the sun's neighborhood come in all sizes and spectral classes — and at least half of them have stellar or planetary companions. In this diagram note the suspected planetary companions to such stars as Barnard's or Lalande 21185. As distance from the sun increases, companions (especially small and faint ones) become harder to see. For more information, see the table on page 9 of the August 1977 issue. Diagram by Mark Paternostro.

BINARIES *continued on page 13*

Evolution in Binary Systems

by
William K. Hartmann

The consequences of stellar evolution can bring about some of the most intriguing phenomena of binary and multiple star systems. During their stable, hydrogen burning configurations, most stars range in size from about 1/10 to 10 times the sun's diameter. Thus, a companion orbiting a star at a distance of one astronomical unit (the Earth-sun distance) would be well outside its primary's outer atmosphere. But in the late stages of evolution, all stars expand enormously, becoming red giants with diameters tens — or even hundreds — of times that of the sun. In these expanded states, the atmospheres of the once-separate stars may interact. If the stars are close enough together, tidal forces will make them co-rotate as a unit. They may deform, transfer gas from one to another, or even touch.

Around 1800, the French mathematician Lagrange showed that such stars would likely deform into a teardrop shape, and that co-rotating, touching stars would assume a shape with a "figure-eight" cross section. Such a pair is called a *contact binary*, and gas may flow from one to the other through the narrow neck of the figure-eight.

By analyzing the gravitational field near a co-orbiting binary pair, Lagrange deduced the motions of material in such a system. His results show that, if either star of a close pair tries to expand beyond a certain teardrop shaped limit (called a *Lagrangian surface*), its gas will flow off its outer surface — usually transferring toward the other star through the pointed tip.

Binaries can therefore follow amazingly complicated evolutionary histories. In any pair of stars, the more massive of the two evolves faster. Suppose in a close pair, with components labeled A and B, star A has more mass. It becomes a red giant and expands to the Lagrangian limit. If

it generates still more nuclear energy and tries to expand further, it sheds gas, most of which is probably transferred onto star B. Star B, which up until now has been quietly "minding its own business", suddenly finds itself accumulating hydrogen from the outer part of star A. The process may proceed to the point where B actually becomes the more massive of the pair. Star A, in the meantime, runs out of nuclear fuel and becomes a white dwarf — a small star with high surface temperature.

Now star B, with its additional mass, evolves rapidly. It becomes a giant and goes through the same process, shedding gas from its outer layers back onto star A. Star A suddenly finds hydrogen raining down onto its high temperature surface, where the hydrogen reacts in nuclear fury and causes nova-like explosions.

With other circumstances, the scenario can be even more violent. For example, if star A had been initially massive enough to evolve into a neutron star or black hole instead of a white dwarf, the addition of later hydrogen may produce other types of explosions or emission of x-rays and gamma rays. Many astronomers, therefore, are beginning to suspect that the evolutionary track of binary systems can explain many of the most puzzling and erratic sources of celestial radiation, such as novae, certain irregular variables, and x-ray and gamma ray variables. 

Two members of a triple stellar system are viewed from the surface of a planet orbiting the third star. The two stars have deformed into a teardrop, or figure-eight, shape that is characteristic of such a close pair (called a contact binary). The gas that flows from one star to another may have drastic effect on the evolutionary track followed by one or both of the stars. Artwork by William K. Hartmann.



WM K HARTMANN
JUNE 1977

BINARIES *continued from page 9*

number of studies on the percentage of systems with different numbers of members. The table compares his figures with the statistics we have just generated by surveying nearby systems. Both results show that *less than half* of all stars are single, with the most probable fraction ranging from about one-third to one-half.

All these statistics have a direct relationship to the problem of whether we will ever find planets and alien civilizations in other parts of the universe. Theories of planet formation, for example, indicate that it is unlikely that planets will form in a system containing two or more big stars, because the complicated forces acting on planetary particles from multiple stars are likely to cause the small particles to disperse before they can form planets.

We can approach these statistics in a different way by studying the distribution of masses in multiple systems. This might allow us to guess whether low mass objects like planets are common or rare in the universe. A few decades ago, the American planetary astronomer Gerard Kuiper studied the statistics of binary stars and concluded that the *mass ratios* (the mass of the secondary as compared with that of the primary) were distributed approximately at random, so that a small but definite percentage of all stars should have companions with planet sized masses. In 1976, Kitt Peak astronomers Helmut Abt and Saul Levy published a survey specifically designed to look at this question. They studied not only the number of stars with companions, but also the masses of the companions. They concluded that about two-thirds of all stars have detectable companions (as shown in Table 1). But from the statistics of companions' masses, they estimated that of the other third of the stars, nearly *all* have companions too small to be detected by conventional means! Some of these companions might be stars smaller than one solar mass, but even smaller ones might be planets. According to this new study, nearly all stars may have at least one companion of some size!

Still more recently, several astronomical theorists have attempted to study another question: What determines whether all the mass in a system will go into one object, two similar sized objects, or one primary and an array of small secondaries? The angular momentum, or rotational properties of the system, may be a factor. Current studies by Carl Sagan and his colleagues at Cornell Univer-

sity suggest that a rather special, narrow range of conditions may be required to divide the mass into a star sized primary and planet sized secondaries. Yet all these results hold out the possibility that at least a few percent of all stars may have companions in the size range of planetary bodies.

But the problem is still not as simple as it may sound. Another characteristic to be studied in comparing binary stars, multiple stars, and planetary systems is the nature of the orbit. The orbits in our solar system are remarkably circular, with all planets lying within 18 degrees of the same plane. Is this true of binary star orbits or orbits in multiple systems? The answer appears to be no. Batten reported studies of mutual inclinations between groups of orbits among 10 triple and quadruple star systems. Of the 10, none is *less* than 19 degrees in inclination, and half are more than 40 degrees in inclination! These would appear to be unlike the solar system and may have a fundamentally different mechanism of origin. On the other hand, a system named BD +66°34 may have three low mass stars in co-planar orbits (as described by John L. Hershey in 1973) — a clue that some binary systems may originate in a process similar to that involved in planetary systems, while other multiple star systems may originate in completely different ways. Another clue in this direction comes from the survey by Abt and Levy, who found that widely separated binaries appear to be fundamentally different from close binaries. They found, for example, that companion stars widely separated from their primaries had the same statistical distribution of masses as ordinary field stars, whereas companion stars close to their primaries (generally with a few tens of A.U.) have a different mass distribution. They concluded that the latter subset of binaries might be related to planetary systems formed by some nebula contraction process, whereas the widely separated group may have formed by a different process.

The orbital statistics of binaries and multiples have always been a problem. As our survey showed, there is a wide range in separation distances, from much less to much more than the size of the solar system. Any naive study of binary star catalogs would reveal two classes of binaries: one with very close orbits, and another in which the orbits are very widely separated — just as Abt and Levy found. For many years, however, controversy has raged over whether these two classes are real. A little thought shows that the two classes may result from our observational techniques. If we try to detect binaries photographically or visually, we will see only the ones that are farthest apart, yielding the widely separated class. On the other hand, the search for binaries with spectroscopic techniques usually relies on detecting the Doppler shift, favored by fast orbital motion. The orbital motion is fastest if the two stars are very close together. Therefore

In this view high in the atmosphere of a planet in a triple system, the star around which the planet orbits shines above the banks of clouds just before setting behind them. In the sky can be seen the planet's large moonlike companion and, much more distant, the other two stars of this system. Triple systems probably account for about 15 percent of all stellar systems and some, like the one shown here, may contain planetary companions. Artwork by Adolf Schaller.

How Many Stars Have Companions?

Number of Members in System	Percent of 25 Nearest Systems (within 13 light-years)	Percent of All Stars (A.H. Batten, 1973)
1	48%	30%
2	36%	53%
3	12%	13%
4	4% *	3%
5	—	0.8%
6	—	0.2%

* Solar System

spectroscopic binaries tend to be the closely paired class. So there has always been a question: Is there a smooth distribution of orbital types or a separation into close and widely spaced pairs, with no middle ground?

Still another problem exists. Even if we could be positive of the present day orbits of all binaries, we would lack data on the *original* orbits. Tidal forces and mass-exchange tend to change orbits' shapes. Just as tidal forces in the Earth-moon system cause the moon to recede from Earth, tidal forces in binaries could cause the two stars to move farther apart — or closer together. Also, as either star evolves to the red giant stage, it could blow off mass which may fall onto the other star or escape from the system, altering the mass distribution of the system and the orbital properties. It's therefore hard to be sure that a division into close spaced and wide spaced pairs is really defining two different modes of binary origin.

More than any previous work, the survey of Abt and Levy tried to take these problems into consideration. As described, the result was that there *are* two groups, and the systems as small as the solar system may have formed by one process, while larger, more loosely bound systems may have formed by another.

It is not hard to think of two processes that might account for these two groups. Those that are solar system size may have formed by processes similar to those by which the solar system itself formed. Most astronomers and geochemists now believe that this process began during the contraction of just one cloud out of many that were contracting to form stars in an open star cluster, perhaps resembling the Pleiades or the group of stars near the Orion nebula. In the cloud that formed the solar system, angular momentum and turbulence were such that one major mass formed in the cloud center, leaving the rest of the cloud as a cooling disk of gas. Various minerals condensed into microscopic grains and aggregated into solid meteorite-like objects as the gas cooled further. These eventually accumulated into planets (see "In the Beginning", *ASTRONOMY*, January 1976). With slightly altered conditions of angular momentum, turbulence or mass distribution, two contraction

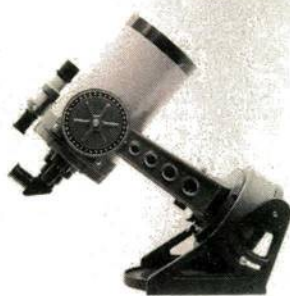
centers might arise, so that the second largest body — instead of being the size of Jupiter ($0.001 M_{\odot}$) — might be a much larger planet ($0.01 M_{\odot}$) or a small star ($0.1 M_{\odot}$), or even a second sun sized star ($1 M_{\odot}$).

Wide spaced pairs or groups could have formed in the same environment if two stars or protostars approached each other at low enough velocity so that one could be captured into an orbit around the other. This capture theory of binary origin was once dismissed by astronomers who calculated that stars in interstellar space could not approach closely or often enough to allow capture. Today, however, we realize that stars begin life in the crowded conditions inside open clusters, because stars form from giant clouds which subdivide into the individual protostars of a cluster. Close encounters may be quite common in these clusters. In 1973, Massachusetts astronomers Thomas Arny and Paul Weissman analyzed the motions of stars in clusters, and found that fully half undergo collisions or near encounters with each other before the cluster stars disperse into interstellar space. In these crowded conditions — especially with intervening gas clouds — close approaching stars might often be slowed enough to go into wide orbits around each other, creating binary pairs and perhaps occasional triples, or pairs of pairs. This would explain why the orbits of such systems often have seemingly random inclinations, since the capture orbits would occur at random.

In summary, the seemingly smooth spectrum ranging from single to multiple stars may really contain two distinct phenomena: formation of systems by co-accretion, and formation of systems by capture. The first process may sometimes produce binary stars, but at other times may form a primary with secondaries too small to be stars — in other words, planets. If planets form in a system with a single star, then the orbital dynamics may be simple enough for the planets to maintain circular orbits, with consequent stable climates that could permit (in some cases) liquid water to persist and life to form. Thus, while binary and multiple stars carry interesting clues about star formation and interactions, the one-third of all stars that *look* single may be the ones that most likely have planetary systems. Perhaps the next generation of astronomers and graduate students, by amassing more statistics, carrying out more theoretical calculations, and using powerful new space telescopes, may reveal what fraction of seemingly single stars actually have unseen companions, including low mass stars and intriguing unknown planets. ☛

Dr. William K. Hartmann is a senior scientist at the Planetary Science Institute in Tucson, Ariz. His research interests are planetary origins and evolution, cratering, and the solar system environment. The material in this article is drawn in part from Hartmann's new introductory text, *Astronomy: The Cosmic Journey*, to be published later this year by Wadsworth Publishing Co.

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ROBOT PROBES: EXPLORING HOSTILE ENVIRONMENTS

by
Stephen A. Kallis Jr.

The surfaces of Venus and Galilean moons of Jupiter, the atmospheres of the giant gas planets — diverse as they are, all these have one characteristic in common: Their environments are highly inimical to man. The most optimistic projections for manned space exploration must acknowledge that many areas of extreme astronomical interest and possible abodes of life exist throughout the solar system that cannot be explored by astronauts for many decades — perhaps centuries. Even with the most favorable extrapolations of current technology, the radiation, pressure or heat of these various environments place them beyond the capabilities of realistically financeable programs.

In those areas of the solar system where humans can (and hopefully will) someday explore, preliminary fact gathering will have to be done with unmanned devices — robot explorers. The reason? Time — for unless the extremely near future produces significant new energy sources, the basic missions to the near and distant planets must be *ballistic*, or nearly so.

In a ballistic trajectory, the space probe or spacecraft follows a “natural” orbit (one of the conic-section orbits). The difficulty with the ballistic orbit is that it tends to be time-consuming. A one-way mission to the outer planets, even with a “grand tour” type of deflection that speeds the mission with a flyby, can take *decades*. And of course, this is the problem with a manned mission, which must be less long than a career. Trips that occupy a significant portion of an explorer’s lifetime (presuming that the crew is supposed to return after reaching the target) are hardly satisfactory ways to explore space.

The alternative is the unmanned or instrumented mission. In the past, however, automated space probes have proven both useful and highly frustrating. They have returned much useful data, but missions have had to be conducted from orbit, or from a single spot on the surface of the target planet. The sheer size of the solar system, and the resultant time lag in communication, are the causes of most difficulties.

The moon, which is really quite close in terms of astronomical distances, is still sufficiently far away to cause a dangerous time delay of about 1.3 seconds from the time a signal leaves to its reception. Assume that someone “driving” a rover by remote control could react instantly to any problem

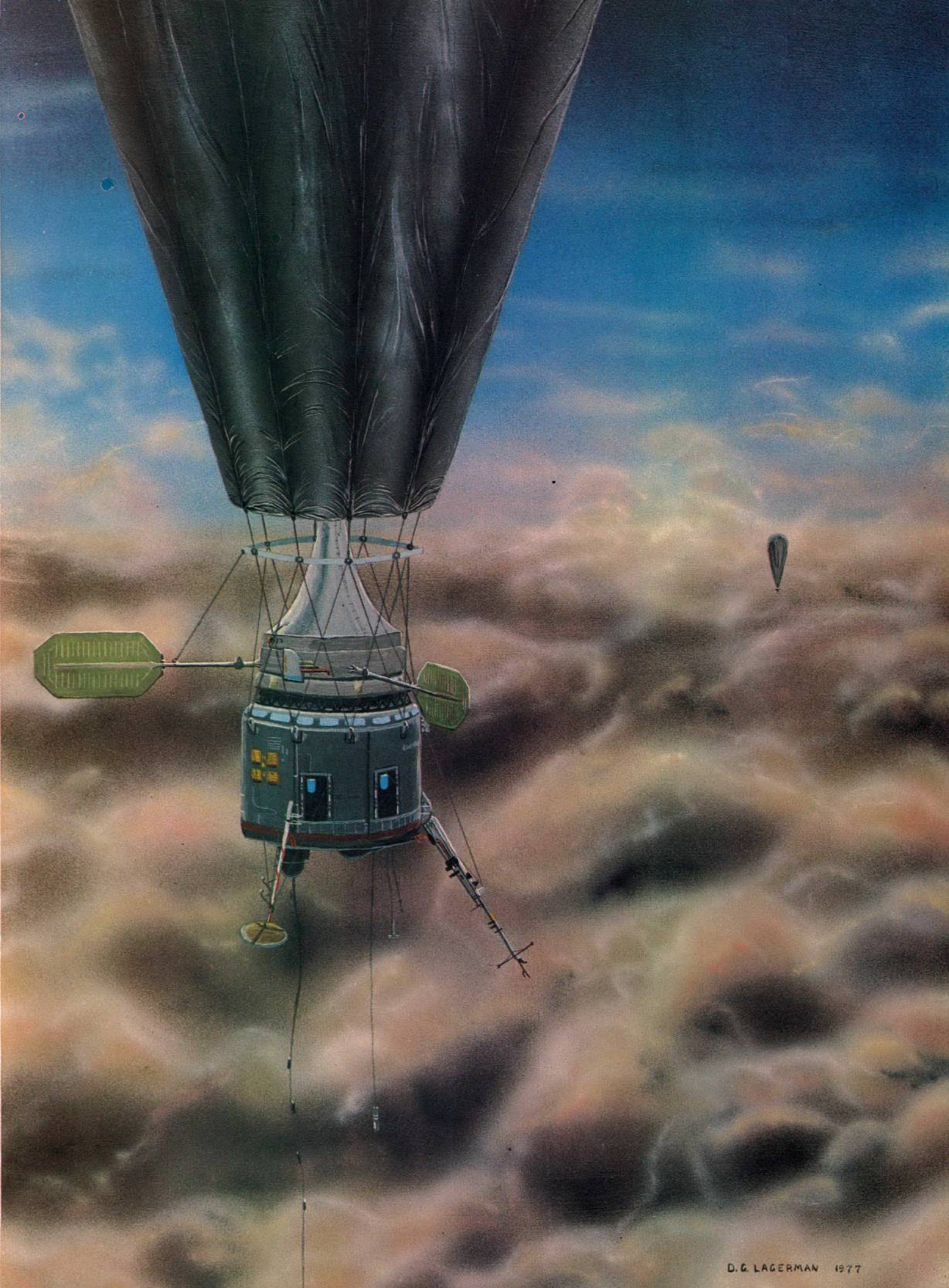
that might suddenly develop. The driver does not know that the condition (a big rock or hole, for example) is taking place until 1.3 seconds after it begins. Then the signal to correct or compensate for the problem (to “put on the brakes”) would take another 1.3 seconds to reach the moon. One Soviet rover had a solution to this problem, but it was hardly practical for any place but the moon: The rover was geared to move so slowly that it could not get into trouble fast enough so that the time lag would be a factor. Such a slow rover is a solution, but there are better ones.

Consider, for example, the great strides that have been made in computerization. Today, computers like those that used to fill whole rooms with electronic equipment are available off the shelf in sizes small enough to fit in an attache case. New technologies can provide customized computers much smaller than that! Computers currently are used in conjunction with Earthbound astronomical instruments, such as optical and radio telescopes. So what could be more natural than building them into instruments that are sent to the planets?

The main advantage of computerizing unmanned space probes is that a computer can be programmed to make decisions. Given logical choices, the computer is able to act on its own. The addition of a computer can therefore make an unmanned space probe “intelligent”, though the intelligence actually belongs to the people who program it.

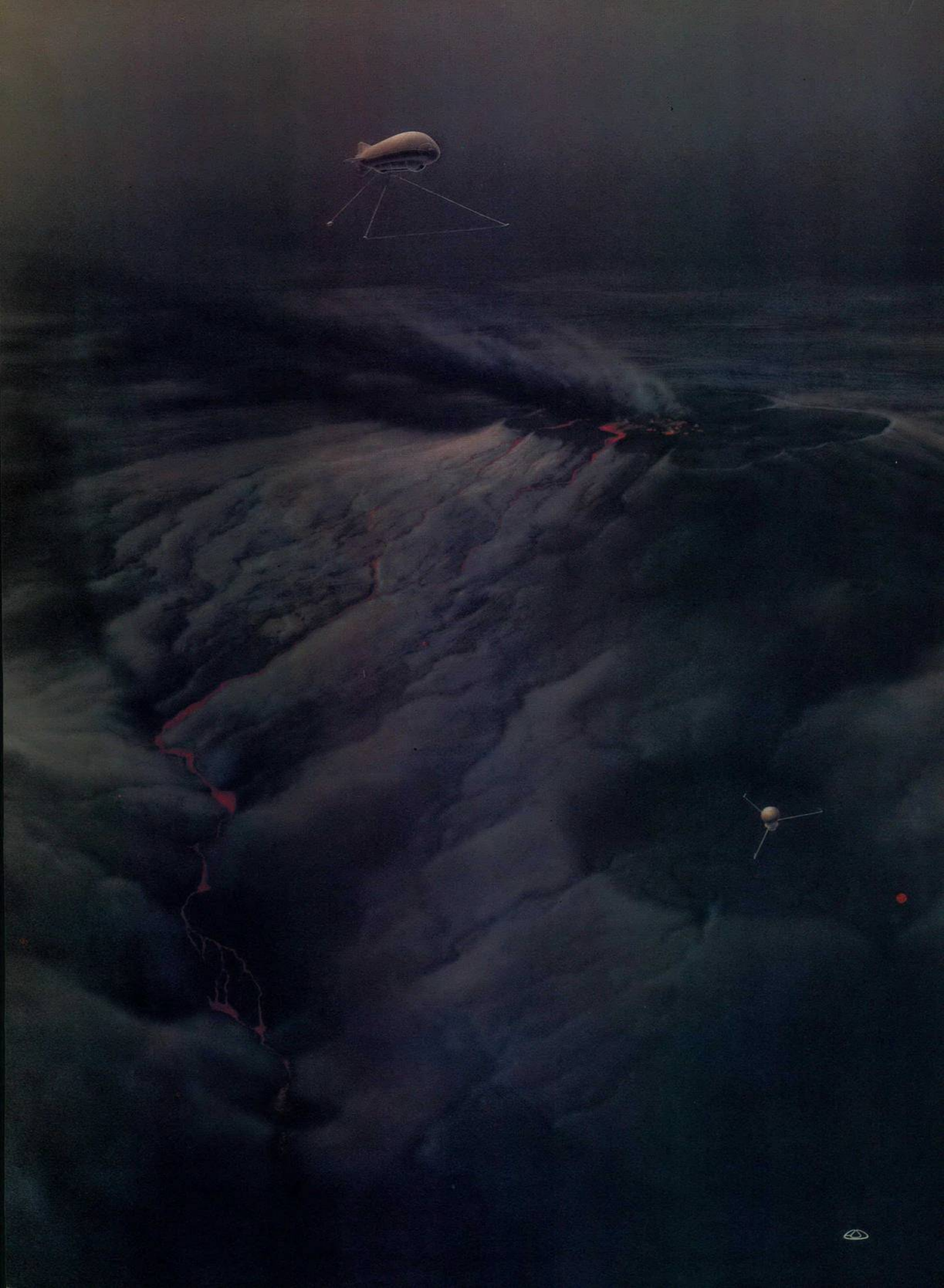
Perhaps the most frustrating aspect of the photographs sent back from the Viking mission to Mars was the close Martian horizon. The almost irresistible urge for anyone standing at that location would be to see what was over the horizon (even if it turned out to be more of the same). The time lag, however, between Earth and Mars is so great (more than four minutes at best, and much longer in the Viking missions) that even the slowest moving rover would be impossible to control from Earth. Sooner or later it would fall into a hole or get

Miles above the turbulent atmosphere of Jupiter, two hot air balloon probes (newly deployed by a parent orbiter) begin their gathering of data. The mission design calls for a full range of atmospheric analysis, measurements of magnetic flux, and wide spectrum photography. Although the balloons are essentially passive, their robot “brains” must be prepared to deal with rapidly changing conditions on their own. These probes have the ability to vary altitude by adjusting inflation of the airbag. Artwork by David Lagerman.





Armed with a full battery of scientific instruments and testing equipment, this well-armored vehicle is investigating the ground around it before moving off across the landscape in the hostile methane atmosphere of Saturn's largest satellite, Titan. This vehicle must have the capability to make its own "decisions" about sudden rapidly changing conditions on the moon's surface, as it is too distant from Earth to be guided every step of the way. Artwork by Mark Paternostro.



Robot Vehicles: Soon A Reality?

by Stephen A. Kallis Jr.

Robotics is difficult enough on Earth; but, when the robot is 35 million to 250 million miles away, the problems become immense.

Man's search for extraterrestrial knowledge has led to the development of increasingly sophisticated unmanned probes. The Surveyors on the moon and the twin Vikings that landed on Mars have probed terrain and automatically performed highly complex experiments. Yet they lacked one significant capacity — mobility. They could only examine material within a few feet from where they landed. Investigation of terrain farther afield was impossible without moving vehicles, but control of such vehicles was out of the question as long as radio signals to and from Earth were delayed by many seconds or minutes.

To circumvent this control-time phenomenon, scientists at the Jet Propulsion Laboratory (in Pasadena, Calif.), under a NASA contract, are currently using a large scale computer to investigate the requirements of unmanned, remote controlled, roving vehicles (RV).

While Earthbound controllers assign goals, monitor progress and solve problems beyond the capability of the vehicle, the rover will act to fulfill the commands while adjusting to unforeseen local circumstances. When the machine cannot accomplish the task, it will recognize that fact, stop, and call for help.

Dr. Donald S. Williams, is responsible for the development of the prototype system. "Although the *initial* concept here relates to an unmanned Mars lander," Williams said, "a more practical and earlier application will be landing on the back side of the moon or, here on Earth, deep water exploration with sonar communications and their associated communications delays."

"Surface manipulators," Williams explained, "such as used in hostile environments here on Earth to handle hazardous materials, are usually controlled in a *teleoperator* mode. The operator watches the action through a protective window or on a television monitor and controls the manipulator via a 'joy stick'. The operator responds to what he sees in *real time* — not seconds to a half hour later.

"On a remote vehicle, the flight computer replaces the joy stick and partially replaces decision making functions of the human operator. The overall program is controlled from Earth, but the immediate, real time movements of the vehicle and robot are controlled by the on-board computer."

The experimental JPL vehicle has *locomotive*, *manipulative* and *sensory* capabilities, which will be under control of a flight computer. The computer will issue forward, reverse and steering commands to the vehicle's wheel drives, and will control a robot arm with six-degrees-of-freedom-reach, panning and elevation.

From various inputs, the computer will recognize potential hazards such as a large rock or deep hole in the path of the vehicle. It will stop the vehicle and issue an alarm to human controllers.

Of primary concern in the JPL development of remote vehicle control are two computer systems: one on-board the remote vehicle, and the other at the control site. Functioning TV, robot and sensor hardware are in operation on a test vehicle.

In future, real life situations, the executive programs in the vehicle's on-board computer will be duplicated in the control site computer. This will permit the controller to try out a command for a unique situation before actually transmitting it to the vehicle.

stuck on a rock. But a computer controlled robot rover could protect itself and steer itself safely from place to place.

For Mars, Mercury, our moon or the surface of a rocky satellite, a rover could be constructed along the lines of a wheeled vehicle. Use of the rover is almost dictated because there is no other effective way to explore the surface and near surface of these bodies. Unlike remote control rovers, though, the

Robot probes may rush in where man fears to tread. The surface of Venus, beset by tremendous atmospheric pressure and incredible heat, cannot be visited by men "in person" with current technology. But robot launched balloon probes such as that portrayed here in a hypothetical "Project Cupid" extend man's reach. Such probes will need the ability to make swift project decisions on their own in the face of suddenly changing conditions. Artwork by Adolf Schaller.

exploring vehicles will have sensors to help them avoid pitfalls.

A typical rover would have some sort of balancing device — perhaps a bubble level or plumb bob. Signals from the device would inform the rover which way is "up" locally, so that it can avoid a slope too steep. Sensors on its wheels would enable it to feel ground that was beginning to give way, so that it could retreat from a dangerous situation. Depending upon the sophistication of the equipment available for the mission, the rover might even be able to see obstructions. If the technology does not permit this, a rover would have to feel its way along. Either way, it would be able to avoid obstacles.

The boon to astronomy from such a rover would be immense. It could send back a series of

photographs from different vantage points, which would permit stereoscopic pictures of the surface revealing a wealth of detail about surface topography. By correlating the surface pictures with those from an orbiting satellite, the details of the planet's characteristics could be extended far beyond what a single panorama from the surface or orbital mapping could produce. The orbiting satellite — like the Viking orbiter — could be used to position the rover's location with great accuracy.

Mars is a relatively friendly environment — compared to Venus or the gas giant planets. Both Venus and the gas giants have thick, high pressure atmospheres — and in addition, Venus is hot! At its closest, Venus is somewhat closer than Mars, but Jupiter is at a vastly greater distance. Each type of planet would require a somewhat different "intelligent" probe.

For a gas giant like Jupiter, there may be no solid surface, and neither a rover nor a static lander could be used successfully. The atmosphere of Jupiter, however, could be explored by either of two types.

One sort of rover would be based upon the hot air balloon. A balloon can ride through winds of violent force without difficulty. A hot air balloon would be necessary because the atmospheres of most gas giants are composed of very light gases, so a pure hydrogen balloon — even filled with the lightest gas known — might be insufficient to create proper lift. But a hot air (or hot Jupiter-atmosphere) balloon could! It would be necessary, therefore, to employ some sort of heat source, perhaps generated by thermonuclear means (beyond current technology) to maintain the balloon indefinitely in flight. In theory, since a balloon travels with wind, atmospheric motion should be virtually undetectable; in practice, atmospheric turbulence might make itself felt.

More practical would be the albatross type of rover in which a robot glider could be used. On Earth, many birds (notably the albatross and the condor) can soar for hundreds of miles without flapping their wings by taking advantage of thermal air currents. Human glider pilots have been able to guide their craft hundreds of miles by similar techniques.

A glider-rover would have to be programmed to detect favorable air conditions — thermals and other updrafts found in an active atmosphere. But the degree of mobility that a glider rover would have would put it in a class far beyond that of a balloon rover. Unlike the balloon, which is at the mercy of the winds, the glider could take advantage of conditions to travel over more selectable routes. It could, for instance, be directed to explore such atmospherically interesting features as Jupiter's Great Red Spot. Even a preprogrammed system could have enough flexibility to be told the general area to investigate — only the second-to-second reactions would have to be made by the

rover. Its basic instructions would come from Earth.

On an outer planet like a gas giant, a glider rover would have to be carefully designed. It would need sufficient power to control its active surfaces (ailerons and rudder elevators, or the equivalent), would be sufficiently rugged to permit maneuvers normal to flight in a gravity more than (in the case of Jupiter) 2-1/2 times that of Earth, while carrying a payload of cameras and scientific gear.

Robot exploration of Venus could involve several other types of rover. A wheeled rover is theoretically possible, but the extremely high temperatures found at the surface might deactivate it fairly rapidly. The ultradense atmosphere of Venus favors glider rovers and balloons, which could take closer readings than an orbiting satellite, but which could stay far enough above the surface to permit a reasonable life expectancy for any onboard electronics.

In one sense, a balloon rover on Venus is more practical than on Jupiter. The atmosphere of Venus is dense enough that a light gas could be used as the lifting medium. The gas would have to be chosen with care, since gases frequently diffuse through the skin of a balloon rather quickly. However, because of the nonflammability of the gases in the Venusian atmosphere (since there is no free oxygen), there are more choices available for a Venus balloon than an Earth equivalent.

The need to develop such rovers is important. Data from a simple lander can be highly misleading — if it happens to land at the wrong spot. A nonroving lander reaching Earth in prehistoric times would have reached a wholly erroneous idea of the composition of Earth if it had landed in the La Brea tar pits. Also, the mascons on the moon suggest that lunar composition is not homogenous, and it is important to remember that landing sites were chosen at different parts of the moon precisely so that a variety of different samples could be taken. Therefore, we have no way of knowing if the rocky plains shown in Viking photos are typical of Martian terrain.

Satellite photographs of Mars show quite different topographies across the surface of the planet. A rover would help bring some sort of relationship to the different areas — something that could only be achieved otherwise by blanketing the surface of the planet with landers.

Such instrumented exploration may not take the place of manned exploration, but it generally will precede and augment the efforts of astronauts. It would be foolish indeed to dispatch a manned expedition to even our nearest neighbors without first having a very good idea of what the manned expedition would need for survival. So far from home, only our robots can tell us what the odds are.

Stephen A. Kallis Jr. worked for seven years on the Apollo lunar landing project. A licensed pilot, he is currently employed by a computer firm in Massachusetts, where he has been involved in engineering work.

"Your 2-inch Unitron," exclaimed Galileo, "makes my telescope look like a mailing tube."

First of all, he couldn't believe that you could buy the 2-inch Unitron altazimuth refractor for less than \$200. But you can. Complete, ready to enjoy, and with all the superb quality you expect from Unitron.

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"Nothing like this in my time," he said, looking at the two coated eyepieces that come with the 2-inch Unitron. One of them is a 25mm-focal length Ramsden-type, with 28x magnification. The other, 9mm, achromatic symmetrical, 78x.

He was particularly intrigued by the viewfinder. "I didn't have one," he muttered. The Unitron 4x, 19mm view

finder with a crossline eyepiece is mounted in brackets with thumb screws for precise alignment.

"I had trouble locating objects," the pioneer astronomer pointed out, admiring the altazimuth mounting, with its slow-motion controls for both axes, and the sturdy adjustable tripod. He found it hard to believe that a precision rack and pinion focusing mechanism and a star diagonal are included at that remarkably low price. And that Unitron has a full range of optional accessories. "Accessories?" he asked, "What are accessories?"

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GAZER'S GAZETTE

Light Pollution: A Losing Battle?

by

Richard Berry

If you've ever stepped outside just to see the stars on a clear night and instead seen a few dull points of light swamped in a murky yellow-green glow, then you know what light pollution is. If you have to search to see the Milky Way, then you've got light pollution! And if you live in any fairly big city, or the suburbs of any big city, you might have to drive 30 to 50 miles before the sky above you is even reasonably natural and dark.

Of course, light pollution doesn't affect telescopic viewing of the moon and the planets — although it combines with ordinary air pollution and smog to make Mercury harder to find in city environments. But it does affect the nebulae, star clusters and galaxies — in fact any celestial object that is not very bright. In rural skies, if your eyes are good, you can see sixth magnitude stars, but in suburban skies you may see only fourth magnitude stars. And in urban skies, it's often hard to see even third magnitude stars! Telescopic viewing is affected the same way: All the dimmest stars are lost in the glow of the sky.

Light pollution comes in two forms: the direct glare from the lights themselves shining in your eyes, and the more insidious general glow that fills the whole sky. You can always escape direct lighting by building a high fence around your backyard, or by asking in the kindest possible way if your neighbor will "Please turn off that *&!# light!" But the general glow of skylight comes from the total effect of 50,000 (or a million) individual lights all shining up into the sky and illuminating the air — illuminating the tiny droplets, the dust present in the clearest air, and reflecting back down into your eye and your telescope. Worse yet, that light still persists for dozens of miles outside the city. As anyone who has flown at night in an airplane has seen, cities shine brightly even 100 miles away!

Astrophotography is affected by light pollution too. The moon and planets are unaffected because they are already so bright, but all deep sky photography is hampered. Because of the artificial sky glow, your exposures have to be cut short to avoid making the sky too bright; of course, you won't get as many stars in a one minute exposure in the

city as you would with a one hour exposure in the country. And if you're taking color pictures, you'll find that the light polluted sky is not the same color as you'd expect from the natural sky.

There are four basic types of lamps used for outdoor lighting, and all cause strange sky colors. *Tungsten lamps* are ordinary light bulbs. They aren't used very much for streetlighting now, as they aren't bright enough. Tungsten lamps cause an orangish glow in the sky but usually aren't too annoying. Today, *mercury-vapor lamps* are the most common type of lamp. To your eye they look blue — a bit ghastly — but to color film they are green. If you get a bright green glow on your city astrophotography, it comes from mercury-vapor lamps. Finally, there are two types of *sodium lamps*: *low pressure* lamps and *high pressure* lamps. Low pressure sodium lamps emit light at just two wavelengths very close together in the yellow part of the spectrum, so they look yellow. They're common in England but fairly rare in the United States. High pressure sodium lamps emit at many wavelengths and have a pinkish-white color which records as yellow on most color films. If your skies come out yellow, it's probably from high pressure sodium lamps. The trend today is to replace tungsten lamps with mercury-vapor lamps and mercury-vapor lamps with high pressure sodium lamps — each step to make them brighter. Your town may be in transition from one type of lamp to another, or there may be only one type used for miles around. But you can be sure of one thing: More lights are being added all the time!

The natural unpolluted sky is not *completely* dark, because light from our atmosphere (called *airglow*) and light from dust inside the solar system (the *zodiacal light*) combine to give a brightness equivalent to about 200 tenth magnitude stars in each square degree of the sky. For comparison, the starclouds in the Cygnus Milky Way are as bright as 300 tenth magnitude stars per square degree. Downtown in a big city, the sky might have a light pollution level of 20,000 tenth magnitude stars per square degree. No wonder you can't see the Milky Way from a city — that 300 simply can't



Night outdoor lighting is used for streets and freeways, advertising, recreation and business. But much of the light is wasted in lighting vacant areas, shining up into the sky, and lighting empty parking lots all night long. From the air at night, a city is an intricate web of mercury and sodium lamps — a virtual galaxy of light obscuring the real galaxy we live in. This city is Toledo, Ohio, photographed from 22,000 feet altitude about 10 miles south of the city. From the air at night, cities are visible for hundreds of miles.

complete with 20,000! From the suburbs, you may have about 2,000 tenth magnitude stars per square degree; the Milky Way's 300 may just barely be visible over the 2,000 from light pollution. You'll find how the sky looks with different amounts with the handy rating scale in Table 1 on page 31. Using this scale, you can make a careful comparison with the written description, and then say, "I've got a rating of seven in my backyard, but at the state park 40 miles from here the light pollution rating is about three — and it's really beautiful out there!"

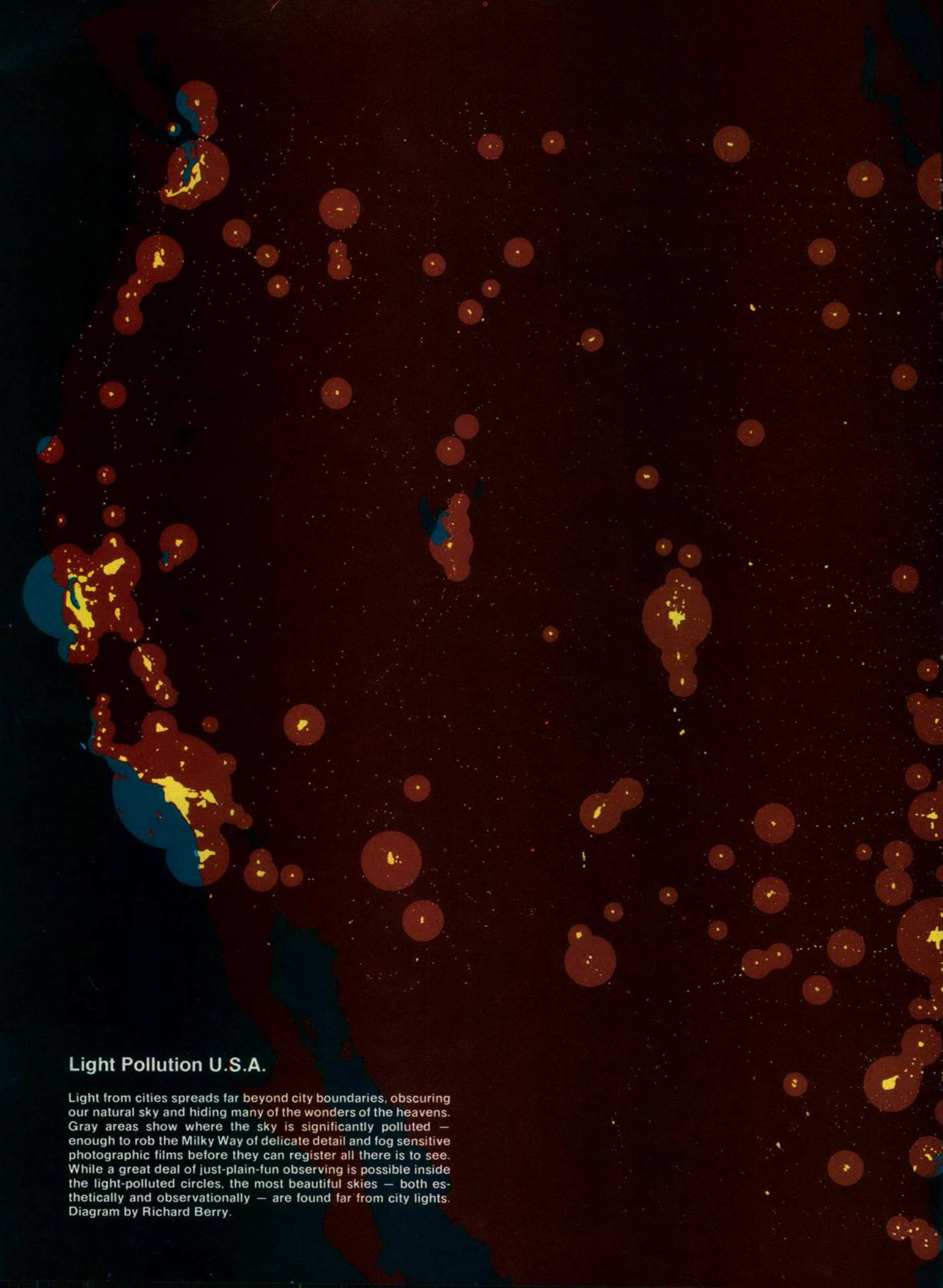
Most astronomy enthusiasts faced with light pollution don't let themselves get discouraged from observing though! After all, there's so much to see — even from the heart of a big city — that you could observe every night and never run out of things to see. The moon is an everchanging show: Night by night the sun rises over the lunar landscape. From the eyepiece of any telescope, you can scan another world where men have now walked, and see giant

craters and the ancient lava flows of the maria. You can watch the planets: Mercury's brief sun-hugging appearances, Venus' phases and dazzling telescopic disk, Mars' polar caps and its faint green features. You can follow the exciting changes as Mars grows closer at opposition and then recedes. Jupiter's constantly moving moons are different each night, and you can watch the Red Spot go right across the Jovian disk on a single night. There is Saturn's delicate beauty, and you will share anew the thrill of discovery each time you find Uranus and Neptune.

Even though you can't find the faintest stars, there are literally hundreds of bright binaries to explore with their contrasting colors, and plenty of close pairs and faint companions to bright stars to test the limits you can reach with your telescope!

Nor is finding deep sky objects impossible. Many of the brighter objects on Messier's list of clusters, nebulae and galaxies can be seen from downtown even with a small telescope — and from the suburbs, at least 3/4 of them yield to anyone who takes the time and patience to look for them.

Faced with a magnificent but disappointingly urban view of the sky, what can you do? "Get away from it all" the ads say, and that is the solution that many astronomy enthusiasts have adopted. Tossing binoculars, telescope, sleeping bag and tent into the car, they zoom off to the mountains 60



Light Pollution U.S.A.

Light from cities spreads far beyond city boundaries, obscuring our natural sky and hiding many of the wonders of the heavens. Gray areas show where the sky is significantly polluted — enough to rob the Milky Way of delicate detail and fog sensitive photographic films before they can register all there is to see. While a great deal of just-plain-fun observing is possible inside the light-polluted circles, the most beautiful skies — both esthetically and observationally — are found far from city lights. Diagram by Richard Berry.





miles away for a night or weekend of observing. Mobile observing has become a way of life for others, with complete campers and motor homes set up to use whenever the fancy strikes. You may have a friend who owns a cottage out in the sticks or on a lake, where you can spend an occasional deep sky observing weekend, or your vacation may take you into unspoiled terrain. Just be sure you choose a time when the moon won't be up when you want to observe.

What do you get for your trouble when you travel far away from city lights? First, you get stars — not the paltry hundreds from the city, but thousands of them filling the sky so full you may have trouble finding your city constellations. And you'll enjoy the stars in a quiet and peaceful environment, too. Then, you get the Milky Way — your own galaxy appearing to arch across the sky — visible at a glance! In dark rural skies, many of the Messier objects are easy to find in binoculars, and you'll see interesting patterns as well: how the galactic clusters hug the plane of the Milky Way and nestle among the starclouds of our galaxy. You'll be able to see the dark clouds of dust which fill our galaxy with your unaided eyes. With a telescope, you'll see faint clusters, find nebulae you can't see in the city at all, and just be able to see the "spirally" arms of some of the nearby galaxies.

But how do you know where the sky will be

More than 40 miles south of Kettle Moraine State Forest where this picture was taken, the city of Milwaukee emits a bright yellow-green glow into the sky, which engulfs the southern parts of Scorpio, Sagittarius, and the many clusters and nebulae in that part of the sky. The sky at this location has a light pollution rating of five, making it suitable for many kinds of observing and astrophotography. Photograph by Martin Eigenburger.

good? It's actually pretty easy to make a *light pollution map* that will let you see where the best sites for observing are. You'll need a map that shows your state and the states that are nearby, a compass for drawing circles, a recent census for towns in the nearby states, and the information you'll find in Table 2 on page 31. All you have to do is look up the population of each town or city on the map, consult the table, and draw a circle with the radius shown in the table on your map. When you have finished, those areas outside the circles are the dark sky places in your state.

You can finish the map and make it somewhat more accurate by drawing the *fillets*, too. Fillets are circles midway in size between overlapping city circles that take into account the light pollution coming from cities on both sides of the rural region between them.

On pages 28 and 29, ASTRONOMY has mapped the light pollution for all of North America. You may notice that large sections of the United States have very few good observing sites in them, at least

as shown on that map — so consider carefully what that map means. The gray circles show places where the light pollution is almost entirely absent — areas that you would rate two or three on the light pollution scale given in Table 1. You can still see the Milky Way, clusters, galaxies, and other deep sky objects very well when the light pollution rating

Light Pollution Rating Scale

How To Use This Table:

Go outside, become *fully* used to the dark, and then directly compare the descriptions below to the actual sky. Don't form your impression right away; take time to look around. It's important not to be blinded by bright lights nearby if you live in the city. If the description of your sky is between two ratings, give it the intermediate rating. Remember that light pollution may vary a few points from night to night.

Rating	Percent Pollution	How It Looks
10	5000%+	Stars are weak and washed out; only a few hundred are visible in the sky. The sky is bright and discolored (usually green or yellow) everywhere. Limiting magnitude 4, naked eye.
8	1000%	The Milky Way is just barely visible if you know where to look for it. The sky is bright and discolored (usually green) in the direction of nearby cities. At the zenith, the sky looks dull gray. Limiting magnitude about 5, naked eye.
6	250%	Stars no longer appear large and brilliant, but there are still many in the sky. The Milky Way is fairly visible high in the sky, but can't be seen near the horizon. Clouds appear bright against the sky. Large areas of the horizon have city glows. Limiting magnitude about 5-1/2, naked eye. To a city dweller, this sky looks magnificent.
4	50%	The Milky Way is brilliant overhead, but cannot be seen low near the brightened horizon. Any clouds in the sky have a grayish glow, and appear bright if they are near one or more prominent city glows. Limiting magnitude about 6, naked eye.
2	10%	A few faint city glows can be seen. Clouds make dark silhouettes against the sky except near the city glows. Stars look large and close; the Milky Way is easy to see.
0	0%	The sky is crowded with thousands of stars to the horizon in all directions. No city glows can be seen anywhere. The stars look large and close, as if you could touch them. The Milky Way is brilliant, and extends all the way to the horizon. Clouds make jet black silhouettes against the sky. Limiting magnitude may be well below 6.

Escape Distances for Light Pollution

Population of City	Distance (kilometers)	Distance (miles)
10,000	20	12
20,000	30	18
50,000	40	25
100,000	50	30
250,000	60	35
500,000	70	42
1,000,000	80	50
2,000,000	100	60
4,000,000	130	80
8,000,000	160	100

At the tabulated distances, the light pollution from a city of the given population will be about 10 percent as bright as the natural sky.

is five or six, so if you want to draw a map for skies rated five or six, use circles just half as big as the ones given in Table 2.

For the astronomy enthusiast living in the 1970s, light pollution is a fact of life — but you shouldn't just have to learn to live with it. What about the 1980s and 1990s when day-bright freeways and fast-food chains will spoil even more of the sky for astronomy enthusiasts and professional astronomers alike? Is there anything that can be done about it? In a few instances, professional astronomers have convinced city governments that an observatory is important, and at least one city has passed a law requiring night outdoor lighting — which is mainly streetlights — to be beamed downward only, and to be filtered to remove the worst of the glare. One shielded light is not expensive, but the cost of shielding all the lights in a city — remember there may be millions of lights — can be high. Furthermore, most people who don't know about astronomy and the beauty of the night sky actually *like* lots of lights — usually for security — and are very hard to convince otherwise!

But lights use a lot of electricity — in some communities an appreciable fraction of the total power consumed. Not only could we save a lot of energy, but in the long term, tight city budgets could be helped by using fewer lights more efficiently. The utilities, however, usually don't want to conserve energy at night when their other loads are low — they'd prefer to see the lights burn.

Energy conservation is a necessity nowadays, if we want energy for the future. And light pollution is all wasted light — light that's not helping anybody! Meanwhile, the real splendor of night is known to fewer and fewer people. We see only the sick glow of mercury-vapor or the garish glare of sodium lamps.

It might not seem that a few avid astronomers can do much, but they can and should try! Energy is being wasted, while one of the unlimited and completely free beauties of nature is being blotted out! 

ASTRONOMY REVIEWS

The Rings of Saturn

edited by FRANK PALLUCONI and GORDON PETTENGILL

222 pages, \$3.25*
NASA (1974)

To an astronomy enthusiast, the rings of Saturn are a thing of beauty when seen through a telescope. To professional astronomers, they are additionally a puzzle of space to be studied from Earth. But to NASA engineers, Saturn's rings are a potential hazard to interplanetary navigation!

Several purposes were served by this special NASA conference on the rings of Saturn. First, the instrumentation for the space probes was discussed, and possible observation programs for during the Saturn flyby were drawn up. Next, the potential dangers posed by the rings had to be understood, especially in consideration of some of the possible trajectories which called for actually flying between Saturn and the innermost ring. Lastly, scientists wanted to discuss their latest data on the rings, and the implications which could be derived.

All three purposes were well served. Readers can learn about many of the "models" for the rings, and many of the suggested formation mechanisms. They can obtain a complete guidebook to the instrumentation planned for the new space probes.

Best of all, readers can "sit in" on a free-wheeling forum about science in action, as top astronomers and planetologists vigorously discuss what they do not know about Saturn and its rings — and what Voyager will tell them. *James E. Oberg.*

*Stock number 3300-00548; available from Superintendent of Documents, Washington, D.C. 20402.

Future Space Activities: 13th Goddard Memorial Symposium

edited by CARL H. TROSS

182 pages, hardcover, \$20.00*
American Astronautical Society (1976)

The top space specialists in the

United States assemble annually to honor the memory of Robert Goddard, the American rocketry expert who opened the road into space. This timely and informative book is a collection of papers presented at the last session, and is an excellent representative sample of the most interesting proposals for the future of the American space program.

Following the customary status report on the "Space Transportation System" (of which the Space Shuttle is just one part), a special report was given on the Spacelab program. This system calls for a European laboratory module to be carried into orbit inside the cargo bay of the shuttle. Instead of being launched like a satellite, the laboratory will be the working space for many scientists, including astronomers.

Astronomers will also be interested in "Planetary Missions in the Shuttle Era" — a paper which presents such tempting possibilities as a Mars sample return, a Mariner Jupiter orbiter, a Titan soft lander, and an asteroid rendezvous. These types of missions could be made possible by the Space Transportation System.

Space applications are discussed in papers on the Air Force space mission, the satellite solar power station concept, and the direct broadcast television satellite.

The third special session dealt with advanced Mars mission concepts, made all the more urgent by the Viking results. *James E. Oberg.*

*Order from AAS Publications, Box 28130, San Diego, CA 92128.

Evolution of the Solar System

by HANNES ALFVEN and GUSTAF ARRHENIUS

599 pages, hardcover, \$11.00*
NASA (1976)

Everyone needs a copy of this book — if just to remind them how much

they have to learn! Mathematics is indeed the language of the universe, as shown by this book's treatment of the creation and evolution of the sun and planets.

This NASA publication was meant to be a progress report for space scientists on what has recently been learned and theorized about the evolution of the solar system. It is not the long-awaited popular book on this topic, and it may look very intimidating to the astronomy enthusiast.

But don't give up hope. True, it requires advanced math background to understand most of the "proofs" of the theories, but the actual theories are presented in a very readable style, interspersed with wry personal comments and anecdotes. There are surprising lessons and insights in this massive volume.

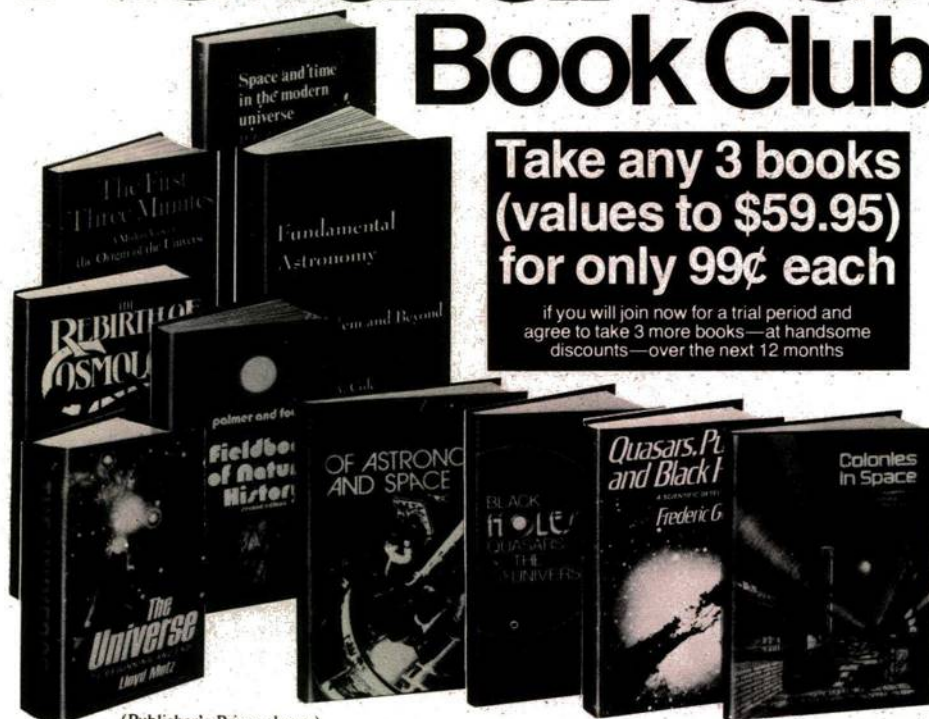
In the section entitled "Remarks on the formation of stars", a reader finds the straightforward and modest paragraph: "There is a general belief that stars are forming by gravitational collapse; in spite of vigorous efforts no one has yet found any observational indication of confirmation. Thus the 'generally accepted' theory of stellar formation may be one of 100 unsupported dogmas which constitute a large part of present day astrophysics".

With candid comments like these, readers might hope that the authors someday rewrite this book for the lay reader. If so, the public will be introduced to many old theories ("lunar capture" is the preferred theory here) and to many new suggestions (Earth probably had a half dozen "pre-moon" satellites which impacted the "new moon"). Without waiting, astronomy enthusiasts should buy this book and hunt through it for scattered comprehensible sections; they are enough to make it worthwhile. *James E. Oberg.*

*Stock number 033-000-06613-6; available from U.S. Government Printing Office, Washington, D.C. 20402.

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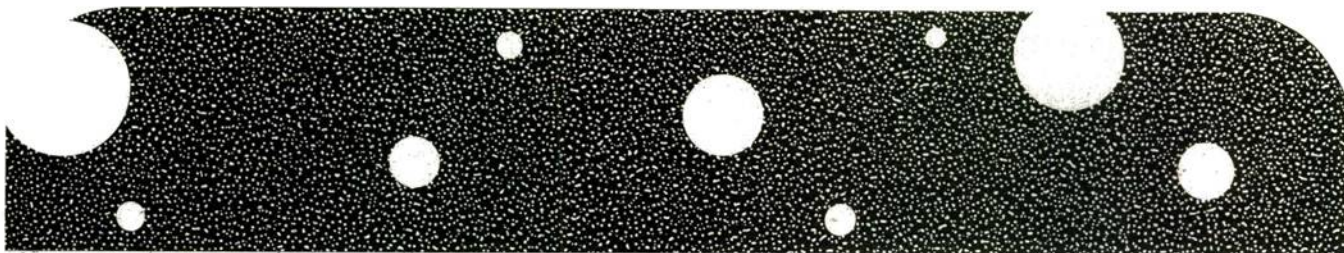
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STELLAR FRONTIERS

Between Stars and Space

by

Robert E. Stencel

If the matter in the universe were spread out into a thin uniform cloud of particles, eventually somewhere in the "cosmic soup", tiny perturbations would bring a group of particles closer together and cause a net gravitational attraction on all the surrounding matter. The nearby matter would begin to drift (slowly at first) into this clump — increasing the gravitational force and accelerating the material infall — and would slowly begin to condense stars and galaxies of stars. If the present universe originated in the big bang, the initial turbulence imparted to the expanding fireball would account for the clusters and superclusters of galaxies we observe now with our largest telescopes.

As a star condenses out of a diffuse cloud of matter, the central regions begin to heat up due to the enormous pressures induced by gravity. Thus thermonuclear fusion, which liberates great energy, begins. This released energy both encourages further reactions by heating the interior regions, and migrates outward through the star, reaching the outer layers and escaping as light. Fortunately, stars do not blow apart since a dynamical balance — called *hydrostatic equilibrium* — between gravity pulling inward and gas and radiation pressures pushing outward occurs in stable stars like our sun.

But what happens at the boundaries of such a sphere of matter? At the boundary of the central core, nuclear energy processes transform the elements in the star's interior. This is known as *nucleosynthesis* — the fusion of hydrogen into successively heavier elements. These processes alter the star's dynamic balance and result in *stellar evolution* — an impermanence of condition which is one of the marks of existence, even on a cosmic time-scale.

The other stellar boundary is the exterior, where star meets space.

Study of the Sun's Atmosphere

In the study of stellar atmospheres, we naturally look to the sun, since its nearness gives us the unique opportunity to see surface detail. Rather hopefully we assume that the sun is a typical star, representative of some reasonable percentage of normal stars of similar characteristics. Direct obser-

vation of the sun reveals that two of the three natural subdivisions of the sun's outer layers have been known from antiquity.

The *photosphere*, often referred to as the solar surface, is quite unlike any planetary surface. It is a hot gaseous zone with an effective temperature of 5,800 degrees Kelvin (nearly 11,000 degrees Fahrenheit) — much too hot for solids or liquids to exist. The light of the photosphere (what we see) actually originates from a very thin layer of less than 250 miles (400 kilometers) thickness, or less than one percent of the solar radius! To understand this, remember that the density of material increases very rapidly as one goes into the photospheric layers. The gases here become opaque enough to stop visible light formed at deeper layers from escaping at all.

The *corona* is a very hot, extremely low density gas lying above the photosphere and extending outward from the sun into deep space. The corona merges into the cooler, expanding solar wind which bathes all the planets and finally merges with the interstellar medium somewhere beyond Pluto.

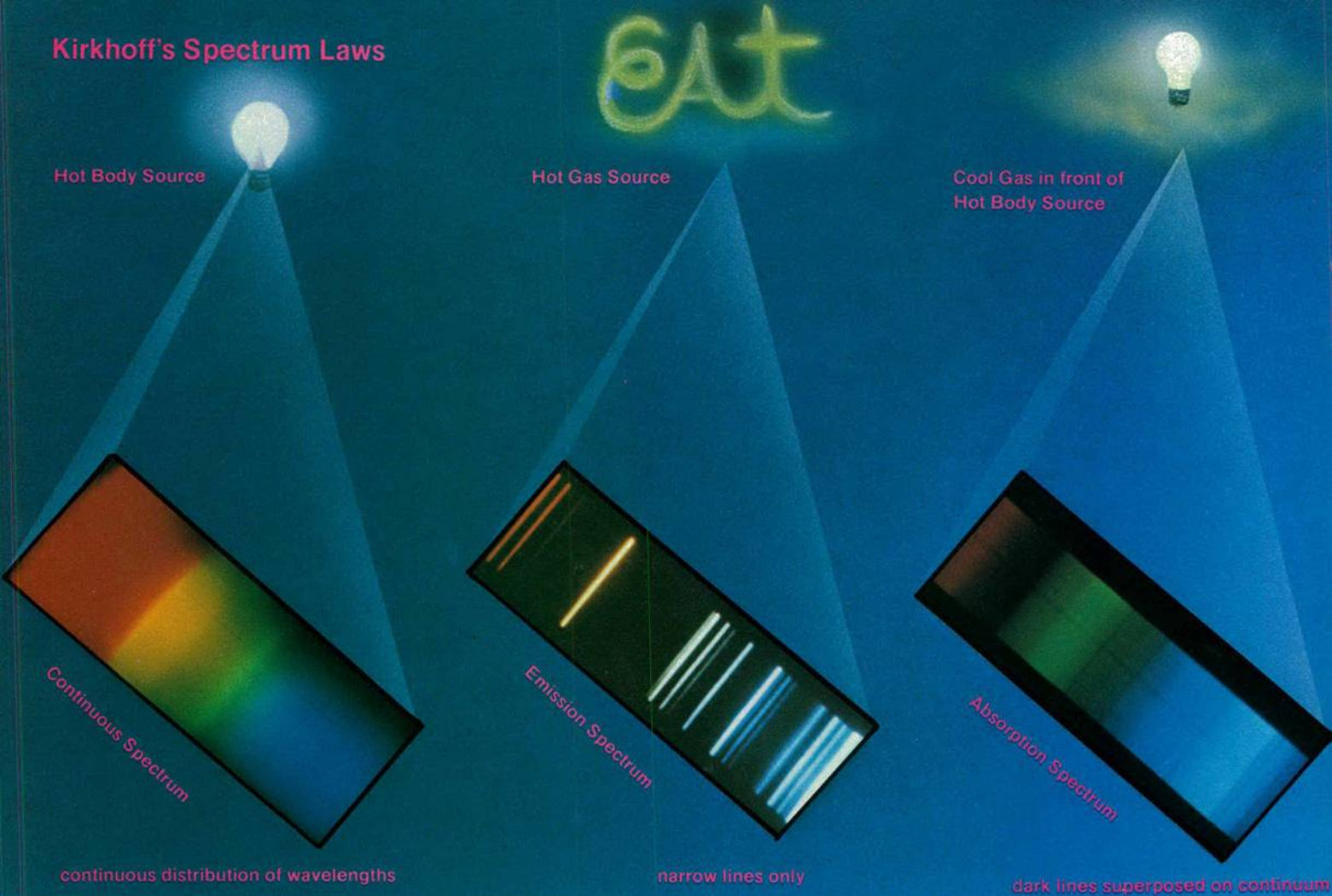
Between photosphere and corona lies a narrow zone which is more difficult to observe. Historically, this region was only observed at the "flash phase" of a total solar eclipse — at the very start and very end of totality, when a colorful flash occurs. Because of the color, this third region of the sun's outer layers was named *chromosphere*. To study this elusive layer, the brief glimpse during infrequent total eclipses is only barely adequate, and without the development of the spectroscope, the nature of the chromosphere might have never been understood.

The visible solar spectrum was first examined in detail by the German scientist Fraunhofer in the 19th century; his original names for the strongest *absorption lines* are still in use today. Two of these

At the boundary between star and space lies the chromosphere. Here the density of "star stuff" falls rapidly from high interior densities to densities a million times less in a few hundred miles, while the temperature begins to rise. Vigorous activity, spicules (the little spikelike bodies) with lifetimes of a few minutes, and prominences (the large archlike structures) with lifetimes of hours to days, mark the transition from star to vacuum. Artwork by Adolf Schaller.



Kirchhoff's Spectrum Laws



strongest lines in the violet were named H and K. They were later discovered to be the strongest lines of singly-ionized calcium. Solar spectroscopists of the later 19th century, particularly Rowland, Hale and Jewell, discovered that the H and K lines possessed the unique property of having emission in the darkest central portion of the absorption everywhere on the solar disk — a property quite unique among the lines of Fraunhofer's spectrum. This central emission became even brighter when observed at the solar limb (the edge of the solar disk). At this location, a few other spectral lines also began to show hints of emission. What did this all mean?

The opaqueness of a spectral absorption line changes greatly from center to edge of the line. Far from the line center, few absorptions occur, and thus a photon can travel through the solar atmosphere unencumbered. But close to line center, the probability of absorption increases and the corresponding path length for a photon diminishes. What this means (in the case of the strong H and K lines) is that in the far-wings we receive photons from deep in the photosphere. Near the line center though, photons originate at higher layers in the atmosphere. By applying Kirchhoff's laws (see artwork above), the brighter center of the otherwise very dark absorption line says that there's a hotter layer above the cooler photosphere — the chromo-

What kind of spectrum comes from different light sources? Hot, dense bodies produce continuous spectra; hot, low density gas produces an emission spectrum; cooler material in front of a hot dense continuum source produces an absorption spectrum. Knowing these rules, scientists can deduce an enormous amount about how luminous objects in space are put together. The spectrum of the sun, for instance, tells us about conditions in the outer layers of the sun and its atmosphere. Artwork by Mark Paternostro.

sphere. It is only in the extremely dark center of the H and K lines (which does *not* allow us to see the layers below the chromosphere) that we can sense its presence at all. The enhanced emission seen at the limb also arises from the hotter chromosphere, and its appearance is possible because at the sun's edge you see dark space rather than bright photosphere behind it.

From detailed analysis of the line profiles of H, K and other lines, the nature of the quiescent chromosphere is revealed. The amazing result is that the temperature actually stops decreasing as we go further from the hot stellar center, and begins to increase outward into deep space.

But why should the sun's atmosphere be hotter than the photospheric "surface" of the sun? On close inspection, the photosphere has a mottled appearance — swarms of bright areas with darker boundaries between them, called *granulation*. These granules actually appear and vanish continuously



over the entire solar photosphere. At any moment, there are several million granules with lifetimes of 5 to 10 minutes each. These granules are thought to be a surface manifestation of an overturning motion called *convection*. Convection is familiar — we see it daily in the motions of boiling water. In the sun's atmosphere, the pistonlike action of rising granules sets up acoustic (sound) waves which carry mechanical energy into the chromosphere. Part of this energy is dissipated in the chromosphere and heats it. Thus the chromosphere is hot!

We can now make a few generalizations. The activity we observe involves the chromosphere, and it appears to result from the natural transference of energy from the star's deep interior source outward to the vacuum of deep space. At the exterior boundary, the dense gravitationally bound interior rapidly changes to vacuum, so the activity at this interface is ultimately a consequence of gravitation.

One can muse over the interesting parallel that all this has on Earth. Man's zone of activity (the habitable zone) is also within a few kilometers (about 1/10 of one percent of Earth's radius) of where the dense crust suddenly changes into thin gaseous atmosphere and ultimately space.

Stellar Chromospheres

The stars are too distant for us to directly

observe any surface detail with conventional telescopes. Only recently, with the aid of new image analysis technology, has it been feasible to "see" a stellar disk. This technique, called *speckle interferometry*, has been successfully applied to the star Betelgeuse using the Kitt Peak four meter telescope. Even so, the visual disk of only 0.050 seconds of arc is just barely resolved. Surface detail is crudely shown; rotation and temperature differences which can be seen when filtered photos of red and blue color are examined. Until orbiting telescopes such as the Space Telescope become operational, however, our study of the detailed nature of stellar exteriors must rely largely on spectroscopy.

The stellar spectrum is a composite of all parts of the light emitting part of the star visible to us. In the solar spectrum, the chromospheric lines are present only in limited areas on the solar disk — particularly in the calcium H and K lines. At the limb, emission lines become more pronounced; we can observe emission in the hydrogen and helium lines, among others. However, this faint emission becomes obvious only because of the darker background. In the case of stellar spectra, we see the average of *all* light leaving *all* parts of the star. Thus the relatively rare disk emission patches and the narrow limb are diluted out, and do not appear in most spectral lines.

The calcium H and K lines, however, under certain circumstances show enough emission in the central core to be detected! Not all stars show this, since the strength of the H and K lines depends strongly on temperature: Above 10,000 degrees Absolute, most calcium atoms are doubly-ionized, and thus the H and K lines (which arise from the singly-ionized form of calcium) are not possible on O, B and hot A stars. Meanwhile the cooler types (F, G, K and M) show very pronounced H and K lines.

Twenty years ago Drs. Olin Wilson and Vainu Bappu published a careful study of H and K lines in the spectra of cool stars. They found that the width of the emission in the core of the absorption line was correlated with the absolute visual magnitude (total light output) of the star. Cool faint dwarf stars (absolute magnitude $M_V = +10$) showed extremely narrow emission cores while the cool but very bright giants and supergiants (absolute magnitude $M_V = 0$ to -5) exhibit much broader emission cores. Our sun (a type G dwarf with absolute magnitude $M_V = +4.7$) fits this general rule as well. The explanation for this observational fact (called the Wilson-Bappu effect) is still being debated. It may be that the emission width is a direct measure of turbulent motions in the stellar atmosphere (that is, bright stars have very turbulent atmospheres), or that the emission width is a natural consequence of the high and low atmospheric pressures of different stars.

Astronomers who support the turbulence model claim that the vast, extended supergiant atmospheres are in a far more highly turbulent state — boiling and smashed by shock waves — than the far more calm and quiet dwarf atmospheres. This hypothesis agrees with our knowledge that the mass lost in the stellar wind in supergiants is millions of times greater than for most dwarf stars. Supporters of the pressure hypothesis remind us that since the supergiant atmospheres are so vastly extended, light from much deeper inside such stars (where conditions could produce broad emission cores without such great amounts of turbulent motion) can reach us. Great observational and theoretical efforts — supported in the past five years by the development of small spaceborne spectroscopic observatories in the ultraviolet, and the development of larger computers to handle the complex physics of spectrum interpretation — have been applied by astronomers, in hopes of settling the question.

In either case, we now know that luminous stars are losing mass into space. Mass loss is no inconsequential matter. Even the sun's tiny stellar "breeze" (which carries away one-ten trillionth of the sun each year) is enough to influence Earth's environment — distorting the ionosphere, causing aurorae and possible weather changes, and perhaps inducing biological mutations. But a red supergiant star like Betelgeuse loses mass at an enormously larger rate (one millionth of a solar mass per year),

thus ejecting the equivalent of an entire solar mass to deep space in only a million years! Many of the bright stars — Arcturus, Aldebaran, Antares, Betelgeuse, Canopus, Mira, Polaris and Pollux, among others — are in relatively transitory states of evolution, which at present have particular atmospheric configurations.

By examining distinctions among atmospheres, we can view glimpses of the average evolutionary paths that the laws of physics require all stars — including our sun — to experience. The peaceful, snugly condensed stars of the cooler part of the main sequence (which are young with lots of core hydrogen to "burn") will soon enough experience the writhing expansions and contractions accompanying their struggle to find a new energy supply. As they grow to giants and supergiants, their atmospheric envelopes will undergo great turbulence, blowing away some portion of the star's own mass. The more spectacular cases of this are the supernovae, and the most beautiful cases are the planetary nebulae — wherein the entire outer shell of a star is lifted off!

Of course, nature recycles. The matter lost from giant and supergiant stars goes on to create future generations of stars. Evolutionary changes of hydrogen to heavier elements slowly alter the chemical composition of the interstellar medium from which new stars form. In fact, the enrichment of star and planet forming gases with carbon, nitrogen and oxygen from nucleosynthesis and mass loss gives rise to some of the conditions necessary for life. Dozens of hydrocarbon molecules have been detected by radio telescopes as resident in the interstellar clouds of our galaxy. Some of these molecules approach the complexity of the amino acid building blocks of life.

We've only recently realized that the coolest, faintest stars — the red dwarfs — contribute to this enrichment process as much as the spectacular show-off giants and supergiants. Each time a slightly-larger-than-Jupiter size star experiences a chromospheric flare event, some limited nucleosynthesis and mass loss results from the flaring area. Individual flare stars do not alone matter much, but since there are so enormously many of them in the galaxy, their combined effect has considerable impact on the chemicals found in the interstellar medium.

Thus, the stellar chromosphere — a thin little zone between star and space, and the edge between matter and vacuum — is the place where we can see the diverse processes of nature in their most active phases. And this is activity which not only affects the surface of a star, but whose influences touch nearby planets, and can affect the course of biological as well as galactic evolution! 

Dr. Robert E. Stencel earned his Ph.D at the University of Michigan at Ann Arbor. His special areas of research are solar and stellar spectroscopy. His ambitions for the future include research with the Space Telescope.

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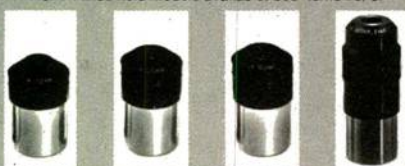
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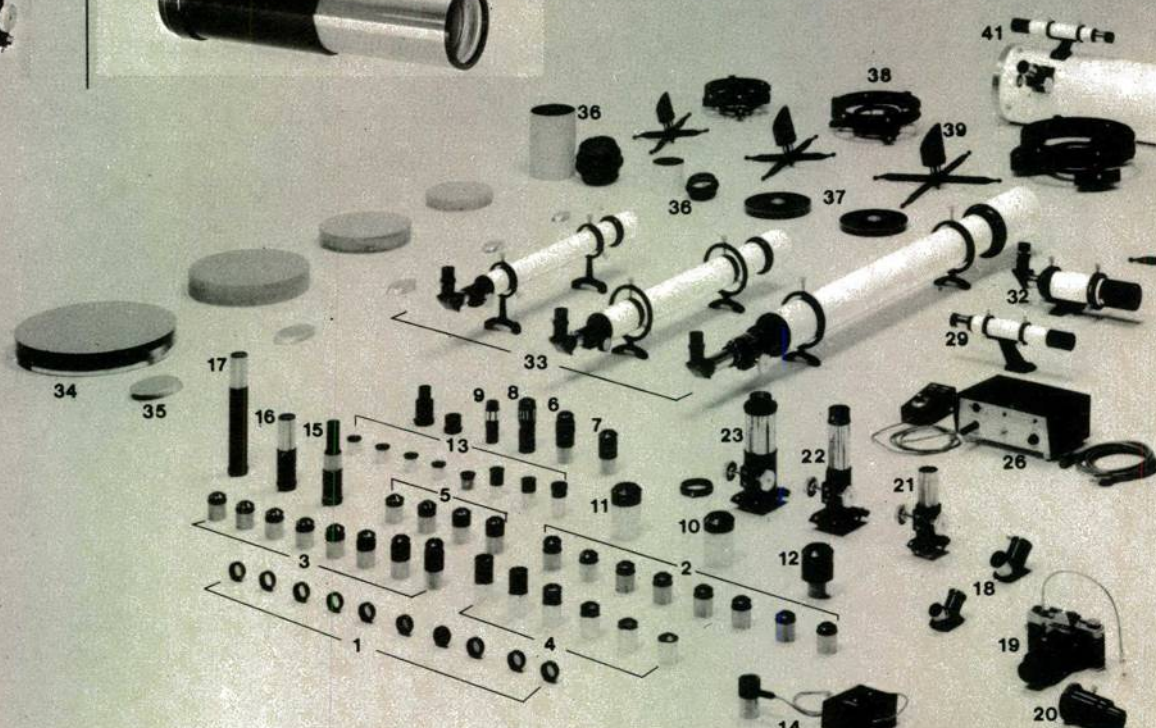
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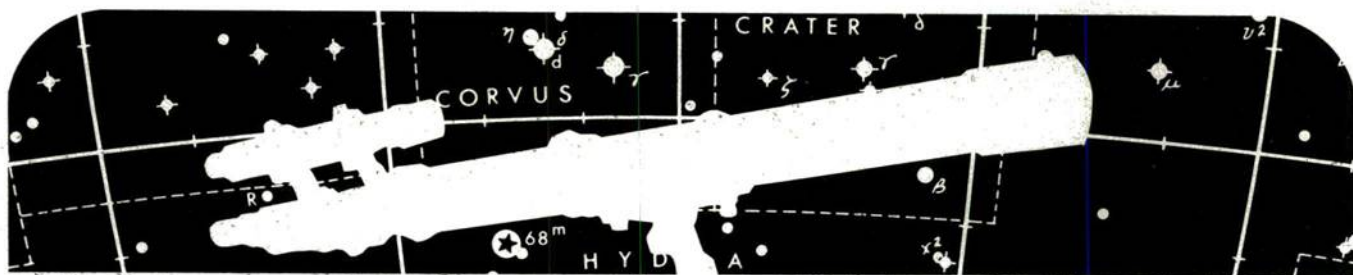
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EQUIPMENT ATLAS

Building A 6" Reflector

Part 4: The Mounting

A telescope with fine optics needs a night with clear steady air for best performance. But to perform its very best, a telescope also has to be supported on a solid *telescope mounting*. Experienced astronomical observers usually prefer a small solidly mounted telescope to a big telescope on a wobbly mounting.

If the image you're trying to look at goes hopping around in a mad dance each time a puff of wind comes by, each time you adjust the focus knob, or each time you touch the tube in the dark, you'll find it difficult to see everything the optics can deliver. After you've put in so much effort to finish your telescope, you certainly don't want to miss out on the delicate festoons of Jupiter's belts, the Cassini division in Saturn's ring, or the critical ability to split doubles to the theoretical limit of your optics — just because your telescope shakes too much!

Of course, a perfectly solid mounting is an ideal to strive for, but how much can you realistically expect? Can you expect to make a telescope mounting at home that will perform well enough? Can you just order a commercial mounting and expect it to deliver the very best performance? And even if you do find an ideal telescope mounting, won't it be too heavy to move?

First, try to forget some of the "facts" you may have heard about telescope mountings. Try to remember that the mounting that's best for somebody else's telescope, or another kind of telescope, is not always best for *you* and *your* observing. Only you and your needs can determine the type of mounting that's best for you.

Many astronomy enthusiasts — both beginners and advanced — are misled by the assumption that a telescope has only one mounting. However, you can build and buy several mounts for your telescope and use the different mounts for different occasions.

For instance, you might buy a fine (but heavy) commercially manufactured mounting for observing from your backyard, where it's easy to carry it out from the garage each time you use it. For observing trips, star parties, picnics, and observing with friends, you might have a smaller, lightweight mount that's not as sturdy, but a lot easier to lug around. And lastly, stored at your uncle's rustic log cabin in Minnesota (where you spend a few weeks each summer), is a mounting thrown together out of rusty old pipes! Naturally, you'd start with only one mount and acquire or make the others later as the spirit moves you. Later, when you build an RFT (or buy a stubby little Cassegrain), there's no reason to get another mounting if you already have three!

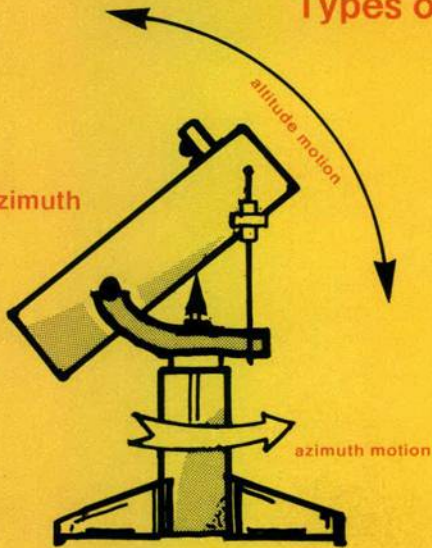
What to Look for in a Commercial Mount

If you want to solve the problem of supporting your telescope all at once, you can buy a complete telescope mount. Of course, as in buying any other large and expensive item, you'll want to know what features to look for.

If at all possible, arrange to see and use the mounting you intend to buy (although in mail order buying, you obviously cannot). Order the manufacturer's catalog and read it carefully. Try to assess the quality of the workmanship on the mount from its finish: Is the finish a cosmetic cover-up job or a durable protective barrier? Are welds filled in and finished properly? Is the design well thought out or is it clumsy in appearance? (Good design never looks sloppy!) Check the size of the drive gears; generally, the bigger they are, the better. Do the gears fit well or are they just filled with heavy grease? Is any wiggle or shake noticeable when you clamp the axes tight and try to move the scope gently by hand? Give it a trial on astronomical objects, too — preferably stars, but if it's daytime, the sun's image (be careful!) will do. While looking at the image, rap the tube of the telescope sharply with

Types of Telescope Mountings

Altazimuth



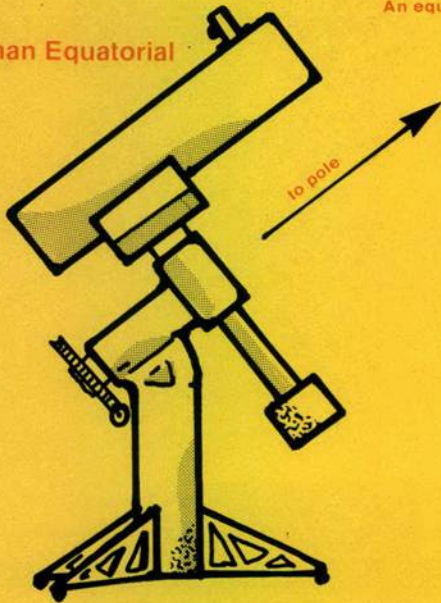
telescope's counterspin

Earth's spin

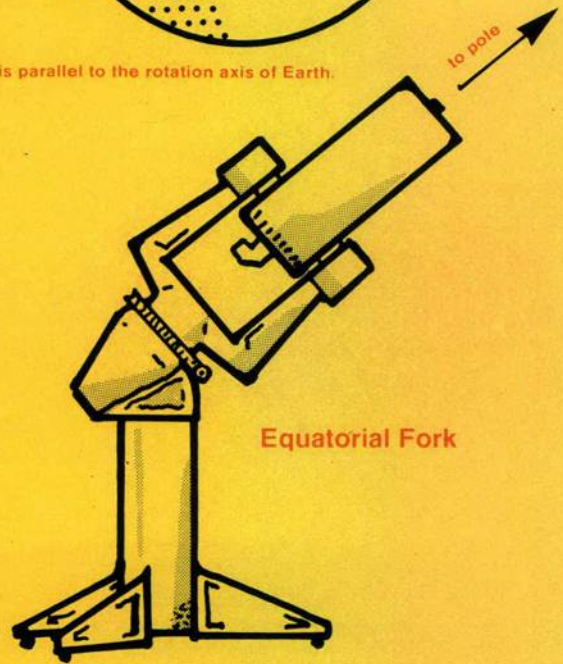


An equatorial's polar axis is parallel to the rotation axis of Earth.

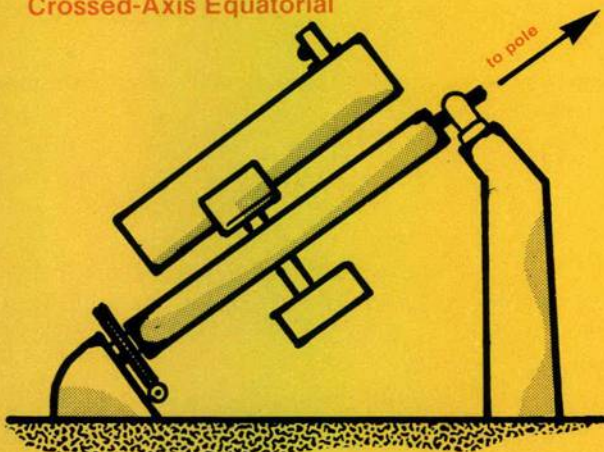
German Equatorial



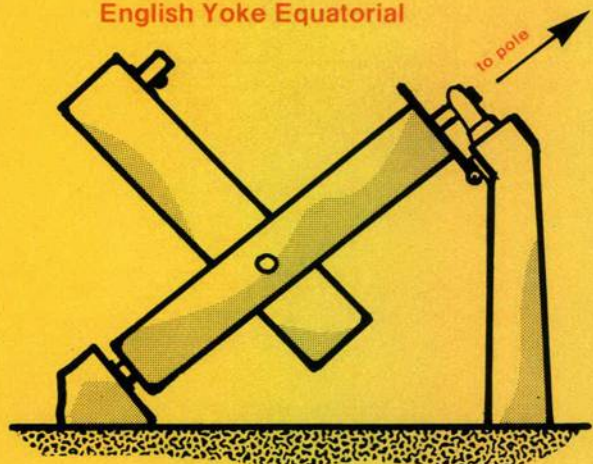
Equatorial Fork



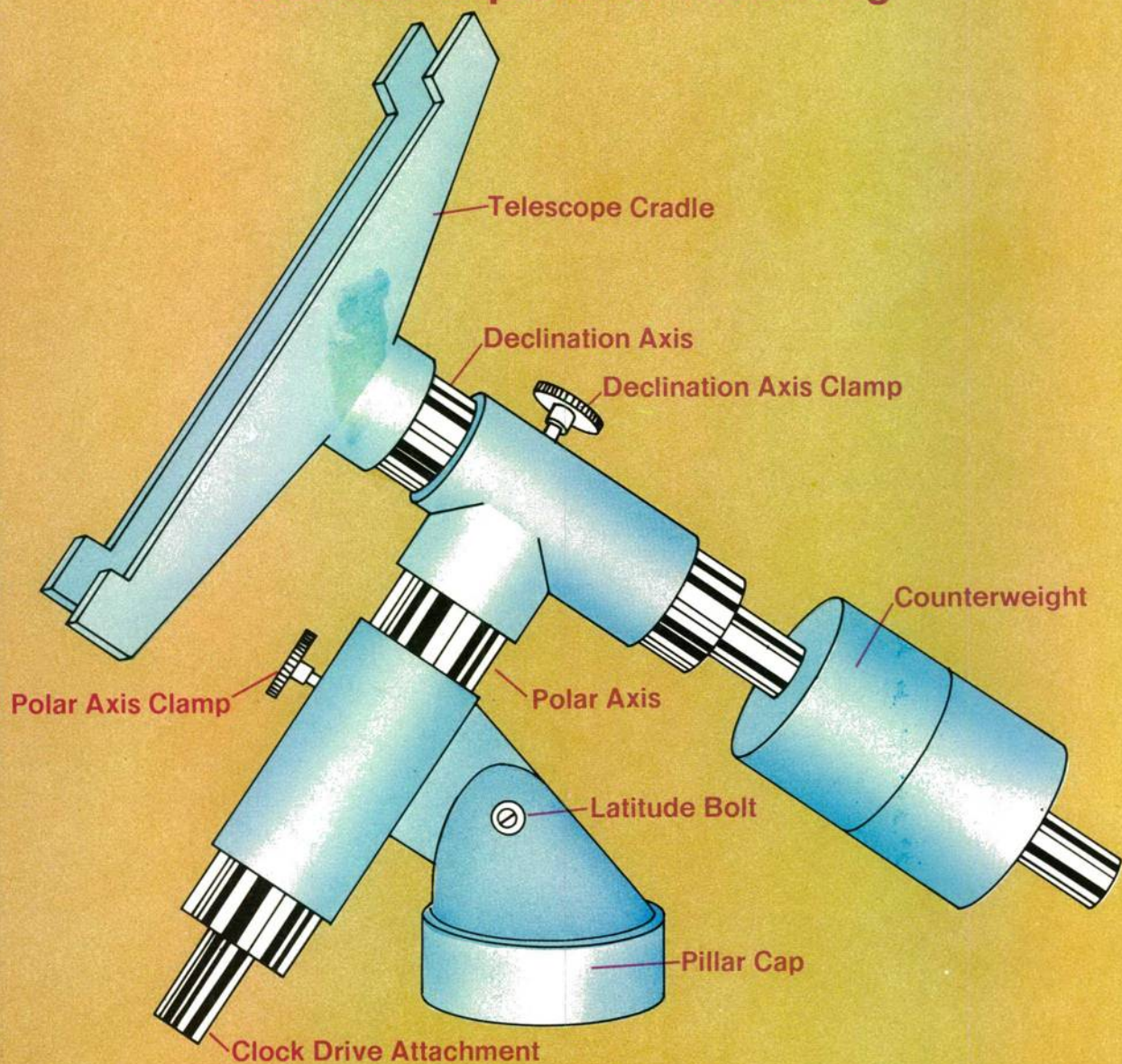
Crossed-Axis Equatorial



English Yoke Equatorial



German Equatorial Mounting



your knuckles. It should shake very little and stop vibrating very quickly. Ask what return privileges you have if it proves unsatisfactory and you want to return it. If the manufacturer guarantees his product, make sure you get it in writing!

Most mountings for small refractors cannot pass these tests, but many mountings for six inch and larger reflectors can and do. As a general rule, it's worth it to buy a "top of the line" mounting from a reputable manufacturer rather than the economy version. The economy version seldom offers anything a good pipe mounting won't give you, but the deluxe model's setting circles, clock drive, and slow motion are worth it. (They're difficult to put on pipe mounts.)

If you think your interest in astronomy will continue to grow, you should seriously consider getting a mounting that's "the next step up" from the

telescope you intend to mount; for instance, buy an eight inch mount for a six inch telescope. You'll be impressed at how sturdy the oversized mount makes the telescope. Later, you can build or buy a bigger telescope without worrying about the mounting. If you contemplate astrophotography at all, the over-size mount is almost a "must", and you'll save yourself a lot of frustration and blurred pictures. Most mounts are designed for visual observing at their rated sizes, but astrophotography demands more from a telescope mounting. The over-size mount will deliver the stability you need.

Making Your Mounting

If you belong to an astronomy club, you probably know someone who has built his own telescope and a mounting for it. He'd probably be glad to help someone else who would like to make his own tele-

scope mount. You can find lots of pictures and cut-away drawings of successful telescope mounts in **Scientific American's** books on **Amateur Telescope Making** — and you'll be amazed at how many ways there are to hold and point a telescope at the sky. Be sure to check your public library for books about telescope making. But don't be too impressed by the precise way someone else has mounted his telescope; remember — it may not be the best way for you and your particular needs. Look and learn, but don't copy; many homemade telescopes are based on a part the builder "just happened to have" rather than standard, readily available parts.

You may think that an equatorial mounting is the "only way to go". That's not true; it's a *good* way, but not the *only* way. Consider first mounting your six inch f/8 telescope on an altazimuth mounting — homemade, since none are commercially available — if you want portability and rigidity. You'll find, probably much to your surprise, that an altazimuth is very practical and easy to operate at any but the *very highest* powers. An altazimuth is perfect for Messier object hunting and searching for comets; in fact, it's suitable for everything but prolonged observation of planets, where tracking in two motions is tiresome.

Altazimuth mounts aren't the "in" thing, but don't let that deter you. It's a fine way to mount your first telescope when you finish it. Later you can complete a sturdy equatorial mount at your leisure.

Next, consider making a pipe mounting as your first mounting. Ignore the humble origin of the materials and follow the rich supply of inexpensive ideas found in **All About Telescopes** (by Sam Brown). For a six inch telescope, you'll want to use at least two inch pipe. (Amazingly, two inch pipe is nearly 2-1/2 inches in diameter.) Turning on pipe threads themselves as bearings, a pipe mount can be sturdy, smooth acting, and quite satisfactory for any type of visual observing you might contemplate. Commercially available pipe mounts aren't a very good bargain; you can buy the pipe at a plumbing supply store for a fraction of the cost. If you aren't handy with tools and do-it-yourselfing, a pipe mount probably isn't right for you anyway. It won't look professional enough to make you happy.

Finally, don't rule out designs like the crossed-axis and yoke mounts just because other types are more popular today. Both yoke and crossed-axis lend themselves to being built at home. They require few "precision" parts; they are the easiest type of home built mount to add a clock drive to, and they are solid mounts, excellent for astrophotography. The biggest disadvantage lies in their bulk: They are not portable telescope mountings. If you build a second portable lightweight mounting from pipe, then between the two mounts you'll have a practical and versatile combination for observing at home and away from home.

Books About Telescope Mountings

Many books contain some information about building your own telescope mounting. Before building a telescope mounting, consult as many sources of information as possible.

All About Telescopes by Sam Brown; Edmund Scientific Co., Barrington, N.J. (1967) — the best available guide to the many ways to build simple and effective homemade mountings from readily available hardware store items, wood and pipe.

Standard Handbook for Telescope Making by N. E. Howard; Thomas Crowell Co., N.Y. (1959) — a complete treatment with everything you need to know, including how to build an observatory.

Amateur Telescope Making (3 volumes) edited by Albert Ingalls; Scientific American, Inc., N.Y. (1966) — hundreds of pictures, useful hints and articles about telescopes, mountings; has entirely a do-it-yourself orientation.

Beginner's Guide to Astronomical Telescope Making by James Muirden; Trans-Atlantic Arts, Inc. (1975) — the altazimuth mount described on the cover is a real beauty; complete with plans and text.

How To Make A Telescope by Jean Texereau; Interscience Publishers, Inc., N.Y. (1959); available in paperback — another excellent altazimuth mount design needing a minimum of machine work.

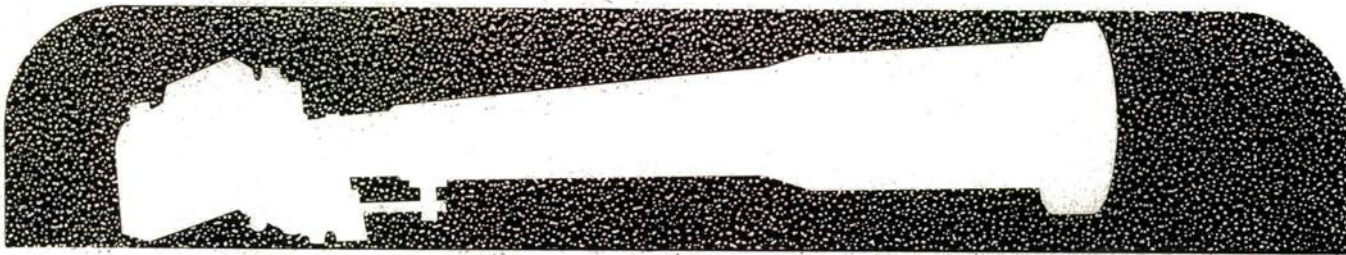
Telescopes for Skygazing by Dr. Henry E. Paul; Amphoto, N.Y. (1976) — lots of information about mountings as well as telescopes; a good buy if you're looking for ideas . . . and probably available at your local library.

Buy or Build? — A Difficult Question

You may have doubts that you know enough to build a telescope and its mounting, but you may also not want to pay the price of commercially manufactured instruments. You may want to build the whole kit-and-kaboodle yourself, but the 17th floor apartment you live in simply isn't suitable for doing the work. Or you may live on a farm where the mail order parts cost too much and are hopelessly beyond your means, but materials and work space are abundant. Your choice has to depend on you and your circumstances. But whether you build or buy, with a telescope you'll make fantastic discoveries with your own eyes; you'll explore the planets firsthand. And, you won't regret it!

Editor's Note: Would you like ASTRONOMY to publish plans for a telescope mounting you can build at home? We'll continue our series on "Making A 6" Telescope" with plans for an elegant little mount you can make with a minimum of fuss . . . if enough readers respond! 🐾





PHOTOGRAPHY IN ASTRONOMY

Astrophotography With Newtonian Reflectors

by
Richard Berry

Your Newtonian reflecting telescope can bring you exciting closeups of the moon, planets, star clusters, nebulae and galaxies — you need only attach a camera rather than an eyepiece to its focus!

Think of the specifications of your ordinary Newtonian telescope. If you describe it like a photographer might describe his lens, you have a super-telephoto 1,000mm f/5 mirror system with razor sharp definition in the center of the field (300 line-pairs per millimeter). Now that's quite a lens! To an astronomy enthusiast, that's an eight inch f/5 Newtonian. But a six inch f/5, f/6, f/7 or f/8, or a 10 inch f/4 or f/5 have impressive credentials too: They're all compact (yet powerful) systems for astrophotography.

Bigger Newtonians are more powerful still — longer focal length and larger mirrors means better resolution and more light — but they pass out of the classification "portable" and into the class of observatory instruments. So, we'll concentrate on Newtonians with focal lengths between 30 and 50 inches, and mirrors between 6 and 10 inches diameter, and see what you can do with one of them — and how to go about doing it!

What kind of picture do you really want to take? If you mainly want moon and planet pictures (without projection — remember this is prime focus), then attaching a single lens reflex camera is

quite simple. You'll need a camera-to-eyepiece-holder adapter for your camera, and you might have to move the primary mirror cell forward in the telescope tube so you can bring the image to a focus on the film. Once you have the adapter, all you need to do is insert the camera into the eyepiece holder (like an eyepiece), focus and shoot! It's that simple!

But if the light rays come to focus too far down the eyepiece tube for the fat camera body to reach, you'll have to modify your telescope a bit. First, carefully measure how far outside the focuser the image lies. Then measure the thickness of your camera body plus adapter plus a bit of leeway for focusing. Subtract the camera plus adapter thickness distance from the focuser distance, and then move your telescope's mirror cell forward by that amount. (See "Building A 6" Reflector, Part 3," *ASTRONOMY*, August 1977 for further details.) Once you've made the change, you'll find that eyepieces focus farther out than they used to — but now you can use your camera also, so the extra distance is usually acceptable.

Once you can focus on celestial objects, what should you do? For the moon, bright planets, and bright stars, you just have to focus, press the shutter, and you'll have your picture. Table 1 gives some handy starting exposures for the moon and a basic exposure for planets — but remember that at prime focus the image of the planets will be *very tiny*. You might try photographing bright stars too, as they will show their colors very nicely in short exposures — a second is usually long enough.

If you expose longer than a second without a clock drive on your telescope's mounting to follow Earth's rotation, you'll get trailed or blurred pictures — so a clock drive is an absolute necessity for some kinds of Newtonian astrophotography. For exposures under a minute in length, you really don't need a very good clock drive; any of the commer-

An eight inch f/5 Newtonian is a fine instrument for deep sky astrophotography, as shown in the photos on the opposite page. The image scale with a 40 inch (1,000mm) focal length reveals detail missed by telephoto lenses, while such a telescope is not too big to be portable. Top: The Pleiades were recorded with a 16 minute exposure on Kodak 103aF Spectroscopic film from Mt. Pinos in California. Note that the guiding is less than perfect, though the picture is still highly pleasing to the astrophotographer. Bottom left: Zeta Orionis (the bright star), the Horsehead nebula (NGC-2024), and the Reflection nebula (IC-434) were recorded in a 13 minute exposure on 103aF. Bottom right: M-101 — a galaxy in Ursa Major — shows spiral structure in this 24 minute exposure on 103aF film. Photographs by Bill Iburg.

cially available telescope mountings will have a perfectly satisfactory drive. You can then photograph fainter celestial objects such as the new moon in Earthlight, and with fast films (the ASA 400 and 500 ones) you can try exposures of the brightest nebulae in the sky (M-42, M-8), the brightest open clusters (the Pleiades, M-44) and globular clus-

ters (M-13, Omega Centauri), the Ring nebula (M-57), and the Dumbbell nebula (M-27). Although one minute exposures won't show faint detail, they'll record the brightest parts of sky objects about as well as you can see them, and you'll be pleased (if not amazed) by the results.

So there's lots of satisfaction to be derived

Polar Alignment for Photography

by

Brad Wallis and Robert Provin

A very useful and extremely accurate way to align your mount is one which doesn't require any more equipment than you probably already have: your drive, telescope or guidescope, and your mounting which can be adjusted in both azimuth and elevation. It's actually possible to routinely take hour-long exposures using lenses with focal lengths from two to eight inches without making a single declination correction. This degree of accuracy means that with an accurate enough drive, you can do piggyback photography without even guiding!

First of all, set up your telescope so that it is roughly aligned. (Standing behind the mount and sighting along the polar axis will do for rough alignment.) Next, locate a star that is near the meridian and near the equator, and center it on your guidescope crosshairs. Observe the direction in which the star drifts during the next few minutes. If the star drifts to the north, the polar axis is too far to the west. If the star drifts to the south, the polar axis is too far to the east. Make the appropriate changes in azimuth, recenter the star, and watch the drift once again. At first the star will probably drift quite rapidly, but after a few azimuth adjustments you will notice that the drift is slowing. Be sure that you are using the same magnification that you would normally use while guiding. Once the declination drift has become unnoticeable during a period of 10 to 20 minutes, your azimuth is properly adjusted.

Now locate a star that is near the equator and near either the eastern or western horizon. Center this star on the crosshair and observe its drift. For a star near the eastern horizon, if the star drifts to the north, the polar axis is too high. If the star drifts to the south, the polar axis is too low. (For a star near the western horizon, reverse these instructions.) Once the drift is observed, adjust the altitude of the polar axis, recenter the star, and repeat the process until no drift is observed in 10 to 20 minutes.

Using this technique, it's quite easy to reduce declination drift to less than one inch of arc in 20

minutes. This is accurate enough to allow two-hour exposures while offset three or four degrees to a nearby guidestar without showing any trace of field rotation. This technique may sound time consuming and, if you start from scratch each time, it can be. It can sometimes take as long as two hours to achieve "perfect" alignment! This time period can be reduced considerably by utilizing several tricks which anyone who has a permanent site can use.

Always begin by disassembling and reassembling your mounting in exactly the same manner. If your pedestal consists of a tube with three removable legs, number the legs and mark the steel tube so that you can always put each leg back in the same place. Next, drill into the ends of each of the legs and tap the holes so that you can equip your mount with leveling screws for altitude adjustment. Don't use screws that are too small: 3/8 inch should be the *smallest*, and the bigger the mount the larger the screw size.

Next, you'll have to think of a way to put your equatorial head on the pedestal so that the two will always be oriented the same with respect to each other. This point — the junction of the pedestal and the equatorial head — will probably be a problem since telescope manufacturers typically make the diameter of the pedestal tube 1/16 to 1/8 inch larger than the diameter of the base of the equatorial head. There are various ways to minimize the shift in orientation between these two parts, but the easiest and simplest method is to place two index marks on both the column and the equatorial head. If these two marks are placed 120 degrees apart, the equatorial head can usually be aligned to within 1/4 degree of the desired orientation.

Once the mounting has been adjusted, how can you take advantage of this at the observing site? Does your site have an asphalt or concrete area on which you can set up? If so, great! If your observing site consists of just a flat dirt area, you will need to install some type of permanent and solid support beneath each of the three pedestal legs. This could be made from three bricks set into concrete with their surfaces just flush to the ground.

Once you have some kind of permanent and solid area to set up your telescope, you'll

from your present Newtonian reflector outfitted with a "plug-in" camera, especially if you have a clock drive. You can photograph a wide variety of objects in the sky with exposures varying from tiny fractions of a second up to a few minutes — and your telescope will prove to be a sharp, powerful telephoto lens.

be able to greatly reduce the amount of time required to achieve perfect polar alignment. How? Simply set up your mount on your permanent site and spend as much time as necessary to adjust both the azimuth and elevation of your mounting. When this is done, you can enjoy the ease of declination guiding for the rest of the weekend and get some really nice photographs. Before you pack up your telescope to leave, carefully mark the location where each of the three elevation adjusting screws rested on the supporting structure. Then, when you next return, set up your mount on those index marks. You will find that your alignment is already close, and within 45 minutes or so of azimuth adjustment, you will again have perfect alignment. Since you have not touched the elevation adjusting screws (you may want to lock these into place so that no one can play with them), you should not even have to touch your elevation although small adjustments may be necessary now and then.

You now have a method of quickly achieving extremely accurate (within .05 degrees) alignment on the pole. Once you have cut declination drift down to one inch of arc per 30 minutes of guiding, you'll find yourself less fatigued after a night of exposing, and you'll also be more successful at obtaining well-guided exposures.

With this method you'll find you still have one major problem with maintaining accurate alignment: Keeping your curious friends who do not appreciate the value of critical polar alignment from clumsily tripping on your mount and knocking your telescope out of alignment!

SUMMARY

- 1) For a star near both the equator and the meridian:
 - a) If the star drifts toward the south, your polar axis is too far to the east.
 - b) If the star drifts toward the north, your polar axis is too far to the west.
- 2) For a star near the eastern horizon*:
 - a) If the star drifts toward the south, your polar axis is too low.
 - b) If the star drifts toward the north, your polar axis is too high.

*Reverse these instructions for a star near the western horizon.

Deep Sky Astrophotography

Deep sky Newtonian prime focus astrophotography is a lot more difficult — but just as rewarding! In deep sky photography, your aim is to photograph faint and distant stars, clusters, nebulae, and galaxies. Exposures in a very good observing location can run more than an hour, and you'll reach stars fainter than 15th magnitude. You'll need to select your films with care, and you'll find many problems arise that don't matter during a short exposure.

First, you'll want to be sure that all the light from the telescope mirror reaches the film — an obvious goal, but not so easy to achieve. The focuser should be oversized (preferably the two inch size for use with a 35mm camera), and should be as short as possible. The farther the focus is from the diagonal mirror, the bigger the diagonal has to be. Since a big diagonal blocks light, the focuser should be short. If you have access to machine shop facilities, consider making your own low-profile focuser; it need not be complicated. Two brass tubes sliding tightly together with a clamp to stop their motion is all you'll need — and it will outperform any commercially available focuser. If you do use a commercial focuser, be prepared to modify it by shortening it and adding a good solid clamp so the camera can't shift during your exposure.

Next, you don't want the optics of your telescope to shift during the exposure — or your star images will not be sharp. "Beef up" the diagonal holder, make sure it's properly tensioned, and that nothing is loose or might move. The cell for the primary should be checked over: Don't let the mirror rest on foam pads or anything soft, because it might shift as the exposure goes on. In fact, it's not a bad idea to cement the mirror into its cell using "Duco" or a "household cement" solvent based glue; they won't harm the mirror, but will reduce mirror shake to zero. (Glue can be removed with a razor blade if you need to take the mirror out of its cell later.)

You'll also want to make sure your telescope's tube is solid enough; heavy-wall aluminum or fiberglass are best, though a well-made plywood tube is easiest to build yourself. If the tube droops during the exposure, the star images will be trailed.

Finally, you'll want to attach a guiding telescope to the Newtonian — very firmly (you'll want to make sure that your guidescope is every bit as stable and wiggle-free as the optics of the Newtonian). That's just good sense; you can't guide on an image that wiggles.

For a guidescope, most astrophotographers choose a small refractor — often simply because they already had one before they built or bought the bigger Newtonian. A refractor is an excellent choice as they need little maintenance, take high powers for guiding very well, and are easy to align in ring mounts that are available commercially. A

2.4 inch (60mm) or three inch (75mm) refractor is usually best.

You'll want a star diagonal to relieve your neck when you guide, and a crosshairs eyepiece. Many neatly self-contained crosshair eyepieces are now available (see the ads in ASTRONOMY). Once you've tightened up your telescope and guidescope into one rigid, nonflexing unit, you can shake the whole assembly and nothing will rattle. Now you need a good telescope mounting so that you can aim the entire telescope/guidescope assembly accurately at the same spot in the sky for an hour or more. An astrophotographic mounting must be very stable — it can't shake in gentle breezes if you want sharp photographs. Its clock drive must track accurately, and it must have delicate, responsive controls in both right ascension and declination so that you can stay "on target" during the whole exposure. Most commercial telescope mountings are designed for visual observing and work well, but they simply aren't up to the challenge of deep sky prime focus photography (see Equipment Atlas).

You can get around the mount problem in three ways. You can buy a top-of-the-line commercial mount (that's been designed with astrophotography in mind), mount your telescope on it, and happily guide away. You can convert an oversized (try a 10 inch mount for a six or eight inch Newtonian) good quality mount into a prime quality mount by replacing the original drive with a precision drive unit, upgrading the declination slow motion so you can make the necessary tiny tracking motions, and possibly reworking the polar axis adjustments for easy alignment on the pole. Finally, you can construct a mounting from commercially available parts or build from scratch — if you can use a machine shop (or know somebody who will help

you). It depends on you, and your needs and abilities. Remember that you can team up with others interested in astronomy — especially if you live in a populated area — and exchange skills and talent.

Guiding

Guiding is the heart and soul of Newtonian deep sky astrophotography. Even the best clock drives have minor faults. For instance, with each turn of the worm gear, your drive might run a bit ahead and then behind. Monitoring the star image in your guidescope, you can correct that error. If the polar axis isn't perfectly aligned on the celestial pole, the telescope will drift off in declination — but with your declination slow motion you can correct that error by keeping the image of a guide star centered exactly on the crosshairs in the guide eyepiece.

But you can't fix all errors just by guiding. The polar axis of the telescope must be closely aligned with Earth's rotational axis. If it isn't, star images will rotate around the guide star, and your picture will look like a polar star trail picture (see the box on polar alignment).

So finally a clear night arrives, and you set up your telescope. Once you've completed aligning your polar axis — then what? You'll load your film (if it isn't already in the camera), carefully focus on a bright star, lock the focus rigidly in place, locate the field of the object you want to photograph, find a suitably bright guide star (about eighth magnitude or brighter), and center it on the crosshairs. Then try guiding for a minute or two to make sure everything is working well. Finally (at last!) open the shutter and start the exposure. How long you expose depends on what film you're using, what object you're photographing and what

Exposure Times for Prime Focus

Telescope	Object	Film Speed (ASA)				
		25	50	100	200	400
f/5 or f/6 mirror	Crescent moon	1/8	1/16	1/30	1/60	1/125
	Quarter moon	1/30	1/60	1/125	1/250	1/500
	Gibbous moon	1/60	1/125	1/250	1/500	1/1,000
	Full moon	1/125	1/250	1/500	1/1,000	—
	Planets*	1/15	1/30	1/60	1/125	1/250
	Nebulae & star clusters	—	—	—	—	60
f/7 or f/8 mirror	Crescent moon	1/4	1/8	1/15	1/60	1/125
	Quarter moon	1/15	1/30	1/60	1/125	1/250
	Gibbous moon	1/30	1/60	1/125	1/250	1/500
	Full moon	1/60	1/125	1/250	1/500	1/1,000
	Planets*	1/8	1/15	1/30	1/60	1/125
	Nebulae & star clusters	—	—	—	—	60

*Jupiter, Mars, and Saturn. To capture Jupiter's moons on film, try an exposure 16 times as long as that for the planet; for example, $16 \times 1/60 = 1/4$ second. Remember that planet images will be tiny.

Astrophotography

Where to Find It in ASTRONOMY

Techniques and Equipment

Astrophotography... In Spite of Myself by David Healy (April 1976) — A humorous introduction to deep sky astrophotography.

Red Light Sky Photography by John Davis, William Tobin, Joel Eaton (August 1976) — You can photograph very faint nebulae with a simple red filter; how it works, examples.

Astrographic Cameras by Richard Berry (November 1976) — a guide to sky photography with big films and big war surplus lenses.

Cold Cameras, Parts 1 and 2 by Richard Berry (February and March 1977, respectively) — How to build and use a cold camera with your telescope.

Astrophotography with Telephoto Lenses by David Healy (July 1977) — What you can do with that telephoto lens you may already own.

Things To Do

Photograph the Milky Way by Hal R. Jandorf (June 1976)

City Astrophotography by Richard Berry (October 1976)

Vacation and Travel Astrophotography by Richard Berry (May 1977)

Film and Darkroom

Choosing B&W Films by David Hudgins and Greg Griffith (May 1976)

— All about films for astrophotography, with comparison shots on different films.

Setting Up an Astrodarkroom by Richard Berry (June 1976) — Basic information on how to start your own darkroom without spending too much!

Developing B&W Astrofilms by David Hudgins (September 1976) —

Everything you need to know to develop your own film; includes comparison photos to show the importance of proper processing.

Is Faster Better? by Brad Wallis and Robert Provin (December 1976) — A beautiful comparison between GAF 200 film and GAF 500 film. Can you guess which is better?

Printing Your Astrophotographs

Basic Printmaking by David Hudgins (December 1976) — Everything you'll need to know to make your own enlargements; pictures, examples.

Printmaking Tricks by David Hudgins (January 1977) — Astrophotography negatives are sometimes difficult to print. Here are the basic techniques you need for getting superb prints from your negatives.

Nebulae by Richard Berry (April 1977) — How to make the best prints from your negatives of faint nebulae and galaxies.

you want the picture to show — but a good, universal trial exposure time is 15 minutes. After looking at your first results, you may want to make it longer or shorter — but 15 minutes is a good length of time to guide since the first painful ache in your back takes about 14 minutes to appear. If your drive is very good, you may have very little work to do — just sit and look at the stars while checking every 10 or 20 seconds that your guide star is still centered. If the drive is not so good, you may have to monitor it continually to correct tracking errors. At least you'll be busy! An egg timer with a bell makes a good exposure timer and will wake you up at the end of the exposure if you fall asleep.

Film Makes the Difference

You can start out with a universal, all-purpose film like Tri-X, and then branch into spectacular black and white with Kodak's spectroscopic films or into color slides with GAF 200 or 500, Fujichrome R-100 or possibly one of the recently-introduced ASA 400 color negative films. (For detailed information, consult "Where to Find It?" for articles that fill you in on what you'll need to know about films — including how you can develop and print your own astrophotographs.)

A Few Extra Things to Know

Up until now, we've assumed you would use 35mm film in a single lens reflex camera mounted on the focuser of the telescope — but you need not use 35mm film or a single lens reflex. You might want to use a larger format film in a home-made film holder. You may want to use a cold camera on your telescope to eliminate reciprocity failure in color and black and white films (see "Cold Cameras, Parts 1 and 2", February and

March 1977), or you may want to use spectroscopic emulsions coated on glass instead of film because glass lies flatter than film. All these things are special projects you can do yourself — but in every case you'll need to know how big a field your telescope can cover. The parabolic mirror of a Newtonian gives perfect images on the optical axis, but suffers from an aberration called *coma* off axis. *Comatic* stars look like little comets pointed toward the center of the field. The lower the f-number of your telescope mirror, the worse coma is! There is a simple formula which relates the maximum acceptable size of the comatic image to the f-number:

$$\text{diameter of field} = 8 \times (\text{maximum acceptable blur}) \times (f\text{-number})^2.$$

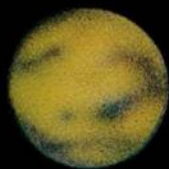
Thus, if you can tolerate a comatic blur 1/250 inch (0.1mm) long [which is pretty good, even if you enlarge the picture 10 times, as the star images are only 1/25 inch (1mm) long], then the field size (in millimeters) will be:

$$\text{size of field} = 8 \times 0.1\text{mm} \times 6^2 \text{ (for an } f/6 \text{ telescope)} = 28.8\text{mm (which is suitable for 35mm film)}$$

At f/8, however, the useful field is more than 50mm — so clearly, larger film could be used!

You'll have to make a choice between fast optics (such as a richest field mirror at f/4), and large fields available at f/8 where you also gain larger image scale, but at the expense of speed. Traditionally, telescopes built between about 1900 and 1930 had speeds near f/5, but today's improved films allow relaxing to f/7 or f/8 if you use spectroscopic films. If you plan mostly color astrophotography, stick with the traditional f/5 focal ratio. ■

Planet Finder

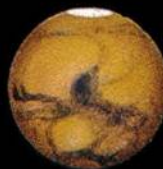


(A) Mercury

Sept. 1
R.A. 11h00m
Dec. +1°40'
Mag. +2.0

(B) Mercury

Sept. 15
R.A. 10h34m
Dec. +8°22'
Mag. +1.1

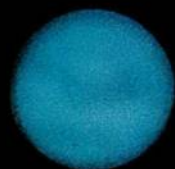


(M) Mars

Sept. 1 15
R.A. 6h02m 6h39m
Dec. +23°29' +23°26'
Mag. +1.0 +0.9

(C) Ceres

Sept. 1 15
R.A. 13h44m 14h04m
Dec. -5°03' -7°32'
Mag. +8.6 +8.8



(N) Neptune

Sept. 15
R.A. 16h49m
Dec. -20°57'
Mag. +7.7



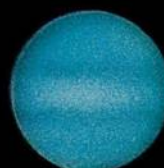
SUN

The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.



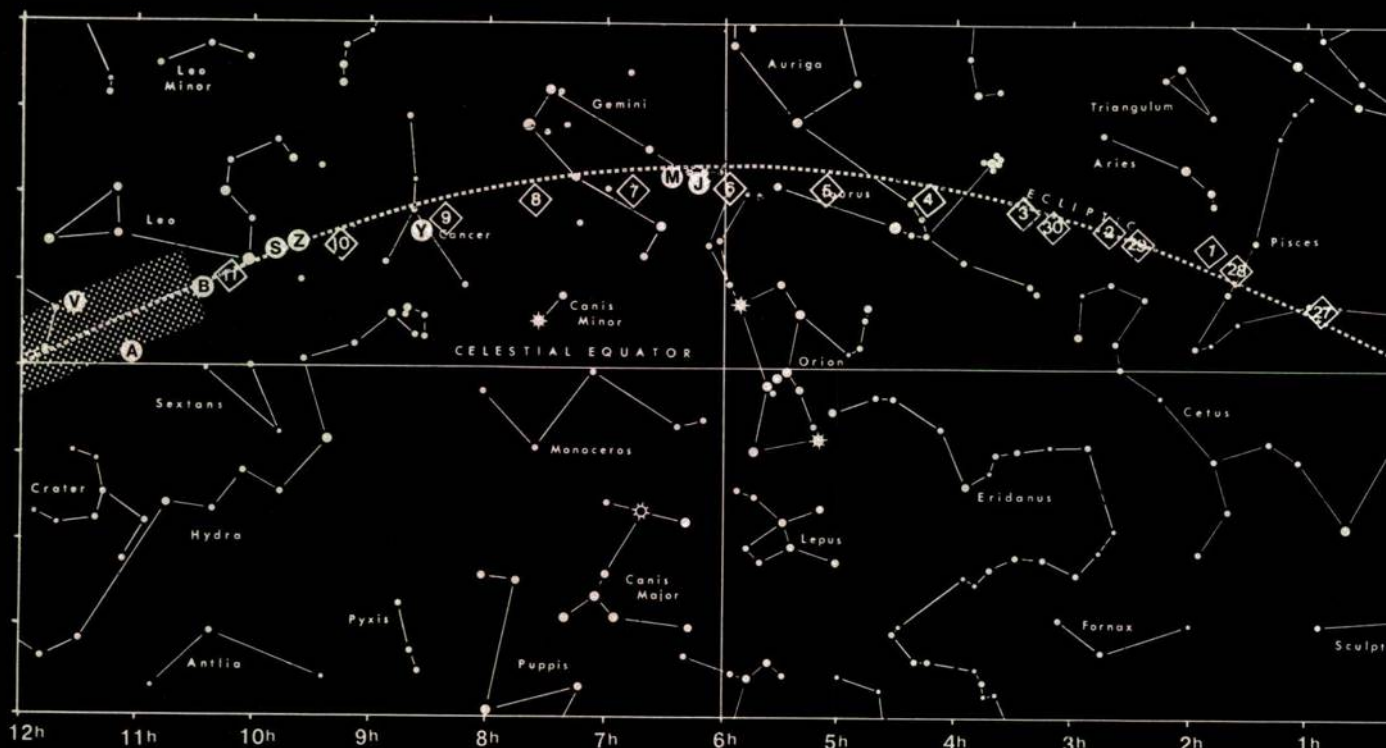
(S) Saturn

Sept. 1 15
R.A. 9h42m 9h49m
Dec. +14°52' +14°19'
Mag. +0.7 +0.8



(U) Uranus

Sept. 15
R.A. 14h27m
Dec. -14°11'
Mag. +5.7



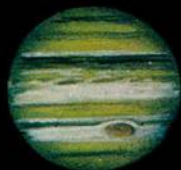
The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec. = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag. = magnitude, a

September 1977



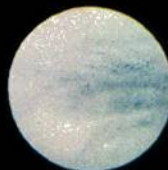
(V) Vesta

Sept.	1	15
R.A.	11h13m	11h39m
Dec.	+9°54'	+7°18'
Mag.	+8.7	+8.6



(J) Jupiter

Sept.	1	15
R.A.	6h08m	6h16m
Dec.	+23°01'	+22°59'
Mag.	-1.7	-1.8

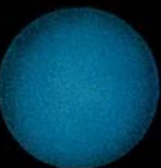


(Y) Venus

Sept.	1	
R.A.	8h30m	
Dec.	+18°52'	
Mag.	-3.5	

(Z) Venus

Sept.	15	
R.A.	9h38m	
Dec.	+14°45'	
Mag.	-3.4	

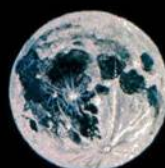


(P) Pluto

Sept.	15
R.A.	13h13m
Dec.	+10°09'
Mag.	+14



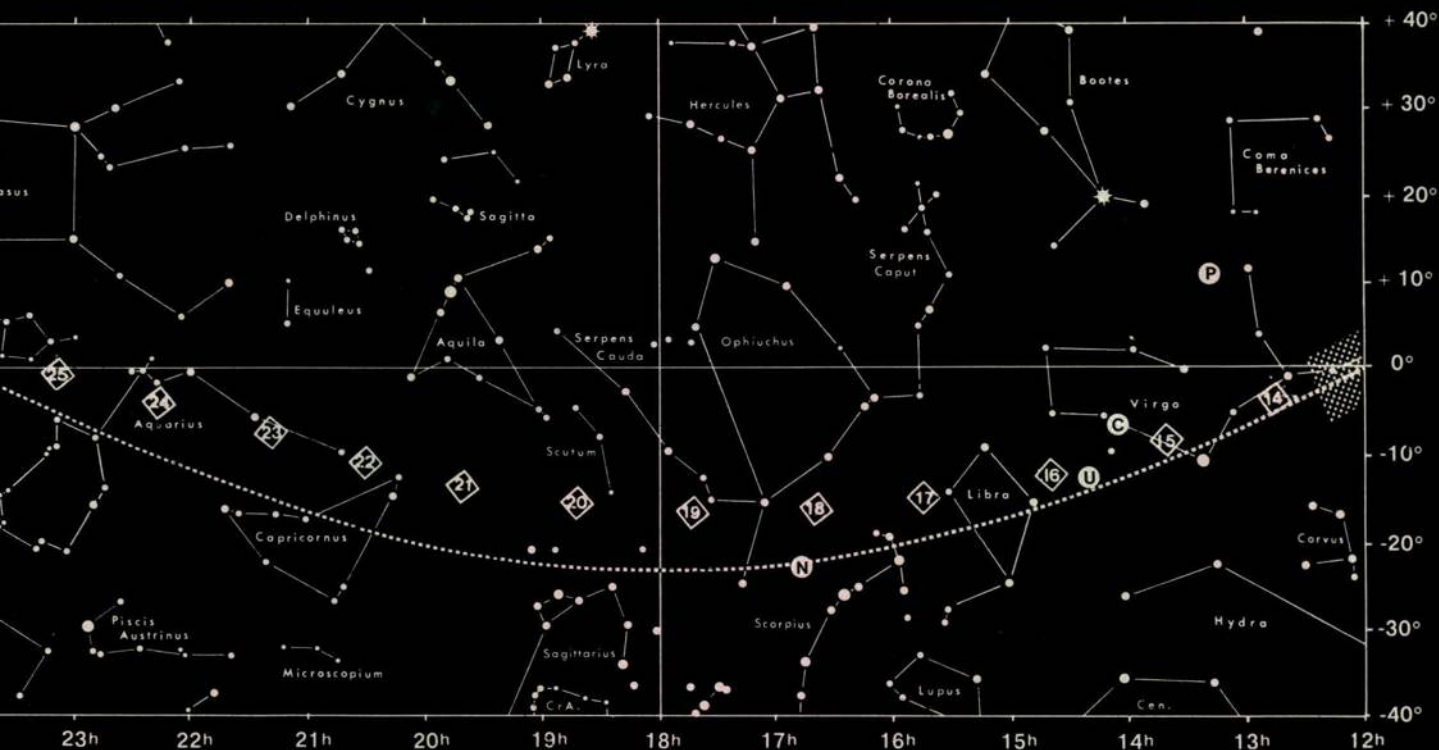
First Quarter
September 20



Full Moon
September 27



Last Quarter
September 5



measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.





SKY ALMANAC

PLANETS PAIR OFF

During the second half of September, you'll be able to see all five naked eye planets in the morning sky, strung like pearls along the line of the ecliptic and ranging in elevation from just above the horizon (Mercury) to near the meridian (Mars and Jupiter). Two planetary conjunctions also make September an ideal month for planet watchers.

Mercury

Following its appearance in the evening sky last month, Mercury will be at inferior conjunction (between Earth and the sun) on Sept. 5, but only two weeks later the planet will make one of its best showings this year. On the 21st, Mercury is at greatest western elongation, appearing above the eastern horizon just before dawn. During the entire second half of the month, you should have little trouble locating Mercury in the morning sky. Around its elongation date, Mercury's magnitude is +0.2, and it brightens even more as the month continues, reaching magnitude -0.9 by the 30th.

Fall mornings (and spring evenings)

You don't need fancy equipment to get lovely photos of the planets, as the pictures on the opposite page prove. Top left: The moon, Mars and Venus were arranged in this striking configuration on the morning of June 12. This is a two second exposure on Kodachrome-II film, made with a 55mm lens at f/4. Photograph by Phillip W. Bradford. Top right: Mercury peeks through the treetops on the horizon in this shot taken on April 1; Venus and the Pleiades are farther up the sky. This 25 second exposure on Focal-100 film was made with a 50mm lens at f/1.8. Photograph by Herbert Lapp. Bottom: Mercury glows through the twilight in this photo taken on April 9, one day before greatest elongation. A 50mm lens at f/1.4 was used for this 20 second exposure on Focal-100 film. Photograph by Norman L. Happe.

are the best times to observe Mercury, because the angle of the ecliptic above the horizon is large and Mercury can

climb higher in the sky. Therefore, even though the separation between Mercury and the sun is not as great

September Satellites of Jupiter

3:00 a.m. EDT, 12:00 a.m. PDT

1	0234	● . . .	16	20143	● ● . .
2	21034	● ● ● . .	17	21034	● ● ● .
3	2014	● ● . .	18	31024	● ● ● .
4	31024	● . ● . .	19	31024	● . ● .
5	30214	● . ● . .	20	32104	● . ● .
6	23104	● . ● .	21	2014	● . ● .
7	4013	● . ● .	22	10243	● . ● .
8	41023	● . ● .	23	2013	● . ● .
9	42103	● . ● .	24	42103	● . ● .
10	42031	● . ● .	25	43102	● . ● .
11	43102	● . ● .	26	43012	● . ● .
12	43021	● . ● .	27	43210	● . ● .
13	43210	● . ● .	28	42301	● . ● .
14	42031	● . ● .	29	41023	● . ● .
15	10423	● . ● .	30	4013	● . ● .

The four major satellites of Jupiter orbit the planet in periods ranging from less than two days to 17 days. You can see them change position from one night to the next; their motions are often evident after only a few hours' observation. You only need a small telescope to detect all four, and you can frequently make out several in rigidly held (or tripod mounted) binoculars. This table shows the approximate positions of the moons at about 3 a.m. EDT on the mornings indicated. The first column on the left shows the date; the second column identifies the moons by their positions relative to Jupiter's disk (1 = Io, 2 = Europa, 3 = Ganymede, 4 = Callisto, 0 = Jupiter's disk). The third column gives the satellites' positions as they appear through a telescope. The orientation of the satellite is given with south up as seen through a standard inverting telescope.



this month as it has been at other times this year, it stands almost vertically above the sun (as seen from Earth) and is easier to find. (See Sky Almanac in the October 1976 issue for an explanatory diagram.)

Venus

Although fainter now than it was in late spring, Venus continues to dominate the eastern sky during pre-dawn hours. Its magnitude this month is about -3.4 — much brighter than any other object in the sky (except, of course, the sun and moon).

Venus is of especial interest on the 18th, when it is less than 1/2 degree away from Saturn. Venus will be by far the brighter of the two — a contrast that will be even more marked if you view the planets with ocular aid. Saturn will appear slightly larger than Venus through a telescope.

The crescent moon passes five degrees south of Venus on Sept. 10, and Venus is very close to the first magnitude star Regulus in Leo around the 21st and 22nd. For telescope users, the planet's angular diameter decreases from 13.2 to 11.7 seconds of arc as its distance from Earth increases from 118 million miles (190 million kilometers) to 133 million miles (214 million kilometers). During the rest of this year, Venus gradually draws nearer the sun, disappearing in the twilight by late December.

Mars

Mars continues to brighten and climb higher in the sky as it approaches Earth. Its distance diminishes from 140 million miles (225 million kilometers) to 123 million miles (198 million kilometers). During September, it is located in western Gemini, rising about 11 p.m. and almost directly south at sunrise.

Mars and Jupiter are separated by only 1/2 degree — about one moon diameter — on Sept. 4. Watch the two planets for several days on either side of this date; you'll see Mars catch up to Jupiter and pass just north of it. Three days later, on the morning of the 7th, Mars, Jupiter and the waning crescent moon are close together in the sky, presenting a pretty tableau.

The arrow in the top photograph on the opposite page points to the quasar 3C-273 — the well-known quasar with a "jet" of material being ejected. This mysterious object was photographed with a 300mm lens at f/4 in a 20 minute exposure on 103aE film. Bottom: Equally mysterious, but much nearer in space, is the most distant planet, Pluto. This photo, taken on April 15 (just a few days after opposition) shows Pluto (arrow) passing through a field in the constellation Virgo. This is a six minute exposure on 103aE film, made with a 5-1/2 inch Celestron Schmidt camera. Photographs by David Healy.

Satellite Shadows on Jupiter

Date	Satellite	Transit Begins (EDT)	Transit Ends (EDT)
Sept. 2	1	12:36 a.m.	2:47 a.m.
2-3	3	10:47 p.m.	1:28 a.m.
9	1	2:30 a.m.	4:40 a.m.
10	3	2:46 a.m.	5:28 a.m.
15-16	2	10:34 p.m.	1:11 a.m.
16	1	4:23 a.m.	6:34 a.m.
17-18	1	10:52 p.m.	1:02 a.m.
23	2	1:10 a.m.	3:47 a.m.
25	1	12:45 a.m.	2:56 a.m.
30	2	3:47 a.m.	6:24 a.m.

1 = Io

2 = Europa

3 = Ganymede

4 = Callisto

Jupiter is almost three magnitudes brighter than Mars' +0.9, but Mars makes up for this comparative faintness with its distinctive red color.

Jupiter

The giant planet Jupiter, like Mars, is growing brighter with each passing month. In September it is located in Gemini, and is the brightest object in that constellation at magnitude -1.8. It, too, is approaching Earth, and its distance during September decreases from 503 million miles (809 million kilometers) to 463 million miles (744 million kilometers).

As Jupiter becomes better placed for observing — it now rises about 11 p.m. and is very high in the south at sunrise — a new season for observing Jupiter's satellites begins. This month, ASTRONOMY resumes its Satellites of Jupiter and Satellite Shadows charts. These moons are visible even through steadily-held (or tripod-mounted) binoculars, and are easy to see with a small refractor. The moons revolve around Jupiter very quickly, presenting a new appearance every night — sometimes changing noticeably within the space of a few hours!

Saturn

Having been too close to the sun to observe throughout August, Saturn reappears in the morning sky during September. Located in western Leo, Saturn is not far from Regulus. You can find Saturn low over the eastern horizon for about 1-1/2 hours before dawn. Don't miss the Venus/Saturn conjunction on the morning of the 18th. The thin crescent moon is only five degrees south of Saturn on Sept. 11.

Next month, on the morning of Oct. 3, Saturn will occult an eighth magnitude star called SAO-98871. This event will occur just before sunrise for most North American locations. In the eastern part of the continent, for example, the disappearance of the star behind

Saturn takes place about 5:50 a.m. (EDT), and reappearance occurs after dawn. Farther west, Saturn will be either too low in the sky or will not yet have risen at the time of disappearance, but the star's reappearance should be visible about 5:50 a.m. (CDT).

Eclipses

A penumbral eclipse of the moon will take place on the night of Sept. 26-27. During this eclipse, the moon will not enter the *umbra* (the darkest part of Earth's shadow) at all, but only the *penumbra* (the fainter outer section).

The moon enters the penumbra at 2:18 a.m. (EDT), with mid-eclipse occurring at 3:29 a.m.; the eclipse ends at 5:40 a.m. You should expect to see darkening only for a short period of time around mid-eclipse, for the penumbral shadow is rarely sufficient to darken the moon's surface very much. In fact, if you didn't know about it beforehand, there's a good possibility you might not notice a penumbral eclipse at all!

A total eclipse of the sun occurs on Oct. 12. The path of totality is in the Pacific Ocean throughout almost its entire length, but it will reach South America just before sunset. Residents of (and visitors to) Colombia will witness totality at sunset. In North America, a partial eclipse will be visible in the afternoon; the farther south you live, the more of the sun will be covered by the moon's disk.

Autumn Begins

The sun reaches the autumnal equinox (the point at which the sun crosses the equator southward in its annual journey around the ecliptic) at 11:30 p.m. (EDT) on Sept. 22, and autumn begins in the northern hemisphere (spring starts in the southern). On this date, the length of day and night are equal; from now until late December, the days will get shorter, leaving more time for stargazing. ☾

OPTICA

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ASTRO SLIDES

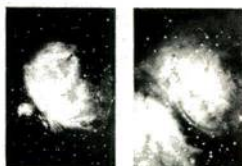
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Trifid Neb. in Sagittarius



M42

M8

GALAXIES

Icy-Blue M51
Edge-on Spiral NGC4565
Irregular Galaxy M82
Pegasus Spiral NGC7217
Edge-on Galaxy in Draco
Close-up of M31, Center
Elliptical Galaxy M32
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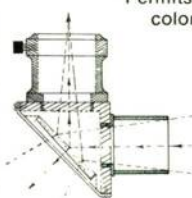
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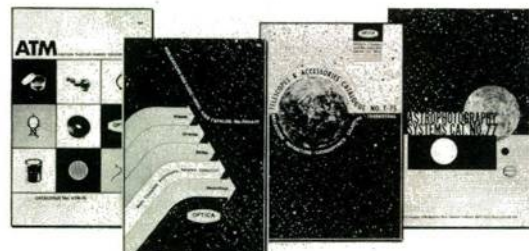
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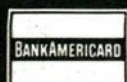


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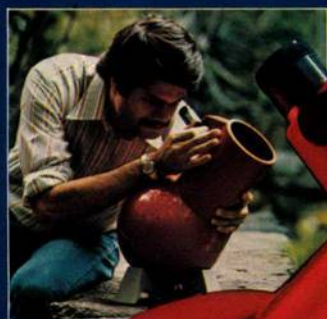
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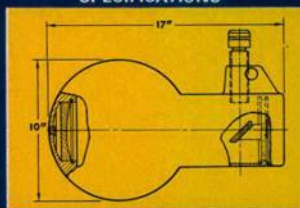
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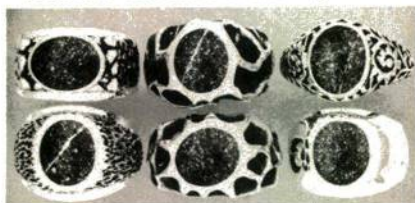
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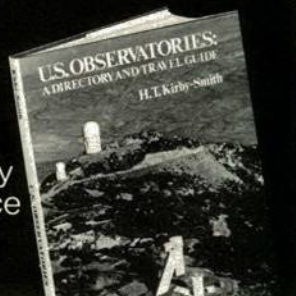
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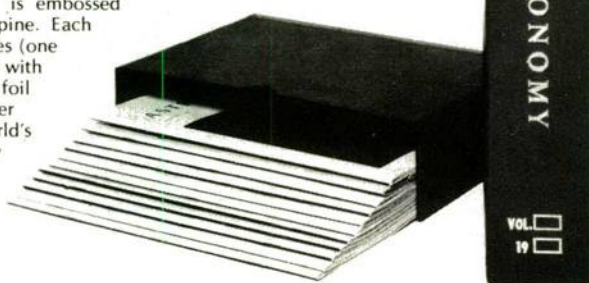
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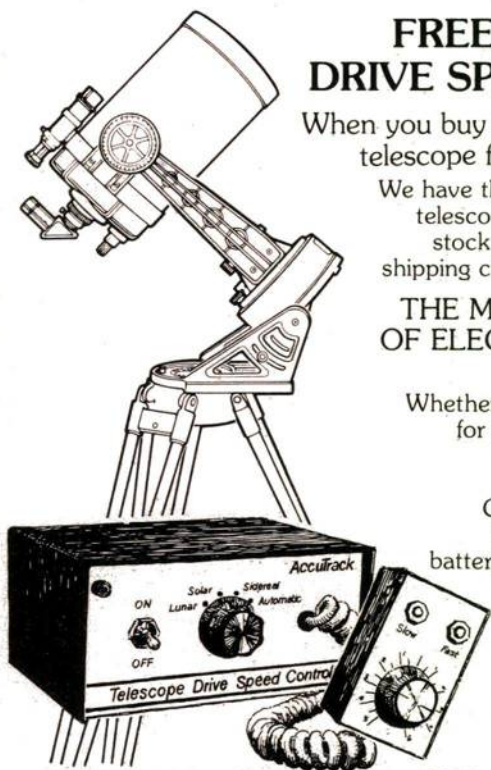
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ASTRONOMY

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ASTRO-NEWS

Latest News From the World of Astronomy

Voyager Probes Begin Planetary Exploration of Outer Solar System

As NASA winds down its Viking mission, a new program — Voyager — is being readied to take its place. Two Voyager probes will be launched in the late summer this year to examine Jupiter, Saturn and their satellites. If all goes well, there is a possibility that the probes may continue on to study Uranus and Neptune.

NASA has already sent spacecraft to Venus, Mercury, Jupiter and Mars. The Voyager project is the next step in the United States program of systematic planetary exploration in which the solar system is used as a natural laboratory.

The outer region of the solar system is considered the source of much important data about the sun and its planets. The inner planets — Mercury, Venus, Earth and Mars — have gone through considerable evolution in the last four to five billion years. In the case of the outer planets and their moons, mainly because of the low temperature that prevailed in the past, we can still find objects where evolution has been so slow that today conditions are not too very different from what they were at the time of formation. By exploring the outer planets, we can go back in time and sample the conditions from which the sun and the planets are believed to have condensed.

Jupiter and Saturn are drastically different from the terrestrial planets, appearing to be composed primarily of hydrogen and helium. Jupiter is larger than all the other planets in the solar system combined, and has 13 or 14 known satellites (the recently discovered 14th has not yet been confirmed). It orbits the sun more than five times farther away than Earth. One Jovian year equals about 12 Earth years, and a day on Jupiter is about 10 hours long.

Saturn orbits the sun from almost 10 times as far away as does Earth, completing one orbit every 30 Earth years. A day on Saturn is also about 10 hours long. Telescopic observations of Saturn's rings are dazzling; the widest visible ring has an outer radius of

85,000 miles (137,000km)! Saturn has more than 10 satellites, including the largest, Titan, which has an atmospheric density comparable to that of Earth.

Trajectories, Speeds

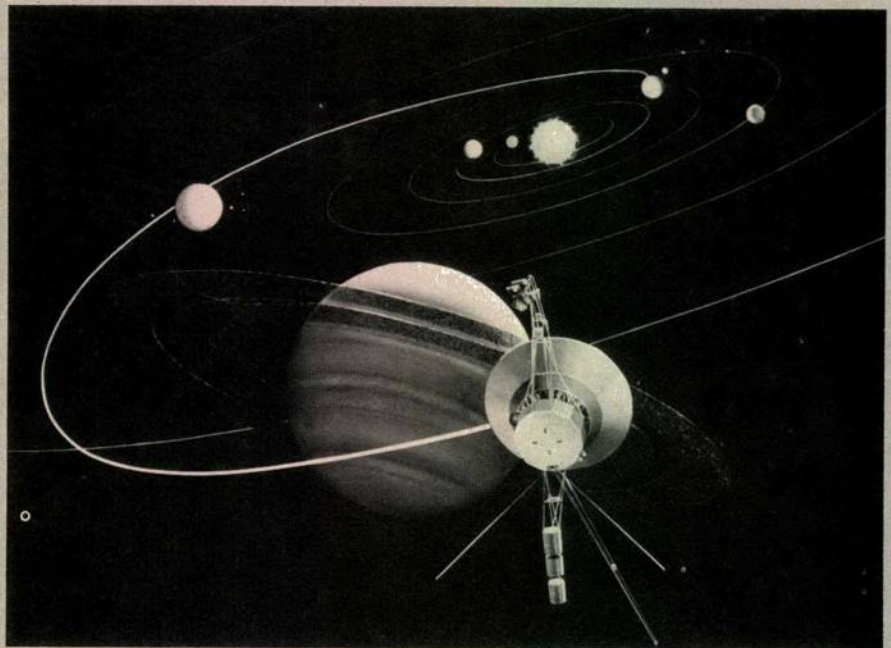
Plans call for the first launched Voyager to fly a slower trajectory, allowing the second spacecraft — launched about 12 days later — to overtake it and reach Jupiter about four months earlier. Jupiter's gravity will sling-shot both Voyagers toward Saturn, with the two spacecraft reaching the ringed planet about nine months apart.

Photography of Jupiter will begin in December 1978, 80 days before the first Voyager reaches the planet. At that time, images of the brightly banded planet will already exceed the reso-

lution of Earth based photographs. For about two months photography will be continued with the spacecraft's narrow-angle camera, which has a 1,500mm focal length lens. In late February, eight days from Jupiter, Voyager will begin coverage of the entire planet with its wide-angle camera (200mm focal length), while the narrow-angle instrument provides high resolution photography of selected cloud features. At the same time, the infrared and ultraviolet spectrometers and the photopolarimeter will be obtaining data on Jovian atmospheric composition and temperature variations, and aerosols in the clouds.

Shortly before closest approach to Jupiter — on March 5, 1979 — Voy-

Voyager continued on page 66



This illustration shows the path Voyager will take after its launch from Earth in early fall of this year. The craft is dominated by the huge antenna needed for long distance contact with Earth. The three canisters at the bottom of the craft are nuclear power generators. The boom at the top holds television cameras and other scientific instruments. The shorter booms are radio antennas; the long boom contains magnetic field detectors. NASA photograph.

What Will Voyager Carry?

Experiment	Principal Investigator	Instruments and Functions
Imaging Science	Team leader, Bradford Smith University of Arizona, Tucson	Two TV cameras with 1,500mm f/8.5 and 200mm f/2 optics, multiple filters, variable shutter speeds and scan rates. Wide-angle field of view, 56 x 55 millirad (about three degrees square). On scan platform.
Infrared Interferometer Spectrometer	Rudolf Hanel Goddard Space Flight Center	Spectrometer-radiometer measuring temperatures and molecular gas compositions, with narrow 1/4 degree field of view, producing measurements every 48 seconds. On scan platform.
Ultraviolet Spectrometer	A. Lyle Broadfoot Kitt Peak National Observatory	Grating spectrometer measuring ion, atomic, and small-molecular gas abundances; spectral range 400-1,600 Angstroms. On scan platform.
Photopolarimeter	Charles Lillie University of Colorado	Telescope with variable apertures; filters, polarization analyzers, and Proof Test Model (PTM) detector. On scan platform.
Plasma	Herbert Bridge, Massachusetts Institute of Technology	Dual plasma detectors, one aligned toward Earth/sun and one perpendicular, with detection ranges from 4v to 6kv.
Energy Charged Particles	S.M. Krimigis, Johns Hopkins Applied Physics Laboratory	Dual rotating solid-state detector sets, covering various ranges from 10 Kev to more than 30 Mev/nucleon.
Cosmic Ray	F. Vogt California Institute of Technology	High energy, low energy and electron telescope systems using arrays of solid state detectors, several ranges from 0.15 to 500 Mev/nucleon.
Magnetometer	Norman Ness Goddard Space Flight Center	Two low field triaxial fluxgate magnetometers located roughly 33 feet (10m) from spacecraft on boom, two high field (20 gauss) instruments mounted on spacecraft.
Planetary Radio Astronomy	James Warwick University of Colorado	Two 33 foot (10m) whip antennas and two-band receiver (20.4-1300 KHz, 2.3-40.5 MHz), detecting planetary radio emissions and bursts and solar/stellar bursts.
Plasma	Frederick L. Scarf TRW Systems Group	Uses 33 foot (10m) planetary radio astronomy antennas with step frequency detector and waveform analyzer to measure plasma waves, thermal plasma density profile at Jupiter and Saturn, satellite/magnetosphere interactions, wave/particle interactions.
Radio Science	Team leader, Von R. Eshleman Stanford University	Uses spacecraft S-band/X-band links during planet, satellite and Saturn ring occultations to perceive changes in refractivity and absorption; celestial mechanics information calculated from tracking data.

Voyager *continued from page 65*

ager 1 will fly about 258,000 miles (415,000km) from Amalthea, giving scientists their first close look at the innermost of Jupiter's satellites. Closest approach to Jupiter's surface will be about 110,000 miles (280,000km). Jupiter will occult the sun and Earth, as seen by instruments on the spacecraft, allowing scientists to make precise measurements of the structure and composition of its atmosphere.

After passing Jupiter, Voyager 1 will examine all four of the big Galilean satellites: Io, Europa, Ganymede and Callisto. Observations of Jupiter will continue for about a month after closest approach, until early April 1979.

The second Voyager will begin its "observatory phase" about two weeks later, again 80 days before closest approach. It will observe four satellites during its inbound trip: Callisto, Ganymede, Europa and Amalthea.

Encounters Scheduled

Closest approach to Jupiter will

occur July 10, 1979. The spacecraft, following a more distant path than its predecessor, will pass 399,000 miles (643,000km) from the center of the planet. The Jupiter encounter period will continue into August.

The first Saturn encounter will begin in August 1980 and will continue through December. On the inbound leg, Voyager will pass within 2,500 miles (4,000km) of the surface of Titan. During the encounter it will also scan the satellites Tethys, Mimas, Enceladus, Dione and Rhea, as well as observe closely the rings of Saturn. Closest approach to Saturn — 130,000 miles (209,300km) — will occur Nov. 12, 1980. Titan, Saturn and the rings will occult the sun and Earth as seen by instruments on the spacecraft.

The second Saturn encounter will begin in June 1981, and will continue through September. Closest approach to Saturn will occur Aug. 27, 1981. The spacecraft will also observe six satellites and Saturn's rings.

The Voyagers each weigh 1,785 pounds. The scientific instruments

weigh a total of 231 pounds for each spacecraft. The Voyagers differ from past planetary Mariner spacecraft, due primarily to the environment into which they will venture and the great distance across which they must communicate with Earth. Since the outer planets receive only a small fraction of the sunlight that strikes Earth and Mars, the Voyagers cannot depend on solar energy but must use nuclear power — radioisotope thermoelectric generators (RTGs). Another obvious difference is the large antenna: 12 feet (3.7 meters) in diameter.

Onboard Instrument Projections

Each Voyager will use 10 instruments and the spacecraft radio to study the planets, their satellites, Saturn's rings, the magnetospheres surrounding the planets, and interplanetary space.

Television cameras are expected to provide scientists with the best pictures of Jupiter and Saturn ever obtained, and the first high resolution close-up images of the Galilean satellites of

Voyager *continued on page 67*

Jupiter, the major satellites of Saturn and Saturn's rings.

Other instruments will probe the atmospheres of the planets and satellites, their magnetospheres and the interactions between these regions and the solar wind, and radio bursts from Jupiter (which emits the strongest radio noise in our sky except the sun). Other objectives include occultation of Earth and the sun by the planets, Saturn's rings and Titan, all-sky surveys of interplanetary space and location, and definition of the heliosphere or boundary of the solar wind.

Trajectories Carefully Chosen

Trajectories were carefully chosen to provide not only good scientific information about the planets, but also about their satellites.

Io, Europa, Ganymede, Callisto and Titan qualify as objects worthy of close study in their own right. They range from larger than the planet Mercury to the size of Earth's moon; Titan is the only satellite in the solar system known to have an appreciable atmosphere.

The Voyager trajectories make use of the favorable outer planet alignment identified during proposed Grand Tour mission studies to achieve flybys of both Jupiter and Saturn. The most favorable opportunity for a close approach to Jupiter with relatively short flight times to Saturn (less than four years) is the 1977 launch window.

The mission also builds on information gathered about Jupiter by Pioneers 10 and 11 — particularly about Jupiter's magnetosphere.

Optional Uranus Flyby

NASA officials have an option to send the second Voyager spacecraft on to the planet Uranus, with encounter occurring in January 1986. The Uranus option will be exercised only if primary Saturn science objectives have been met by the first spacecraft and the operating health of the second warrants such an undertaking. There is also a possibility — because of the alignment of the outer planets — that the second spacecraft could be targeted to continue on to Neptune after its encounter with Saturn.

Both spacecraft will eventually escape from the solar system after completing their encounters with the giant planets. They will be tracked by radio from Earth as long as possible to obtain science data on the heliosphere, particularly to study interactions between solar and cosmic radiation.

Tracking Facilities

After launch, tracking and data acquisition will be performed by the Deep Space Network (operated by the Jet Propulsion Laboratory) with stations in

The Moons of Mars: 100 Years Since Their Discovery

It's been 100 years since the discovery of the satellites of Mars was announced by Asaph Hall of the U.S. Naval Observatory. Deimos was first seen by Hall on Aug. 11, 1877, and Phobos six days later — the gap being caused by bad weather at the site of the old USNO on the Potomac. The first of several scientific meetings to commemorate the centenary of the discovery was held by the Royal Astronomical Society in London, England in early May. Historical developments were discussed in addition to the latest news from the Viking studies of the Martian moons.

Following the initial excitement of their discovery, interest in these two tiny satellites, orbiting close to Mars where they are difficult to observe, waned rapidly. Little progress toward understanding their nature was made until the late 1950s, when Russian astronomer I.S. Shklovskii suggested that they might be hollow artifacts (artificial satellites). This resulted in an upsurge of interest.

Dr. J. Veverka of Cornell University described spacecraft observations of the moons, including results from a close flyby of Phobos made a few weeks before the meeting. The skill of the Viking team in adjusting the orbit of one of their orbiters to pass within 60 miles (100km) of Phobos is one of the great unsung achievements of the space age. The diameter of Phobos is itself about 12 miles (20km) long, and this close approach was the nearest they dared risk with the valuable Viking. The last thing anyone wanted was a collision between Viking and the Martian moon!

The new pictures show more detail than ever before, including strings and clusters of craters that appear to be secondary impacts, and many parallel grooves around the waist of the ellipsoidal moon. It might seem surprising that secondary impact craters formed by debris from a large impact can exist on a moon where the escape velocity is

only 32 feet per second, but Veverka pointed out that ejecta from large impacts may escape from Phobos without escaping from Mars. Following their own orbit around the planet, they may then reimpact to produce the secondary craters when their orbits intersect with Phobos again, years or decades later.

As for the grooves and striations, they seem to be evidence that Phobos is being pulled apart by the tidal influence of Mars — literally stretched along the axis pointing toward the parent planet.

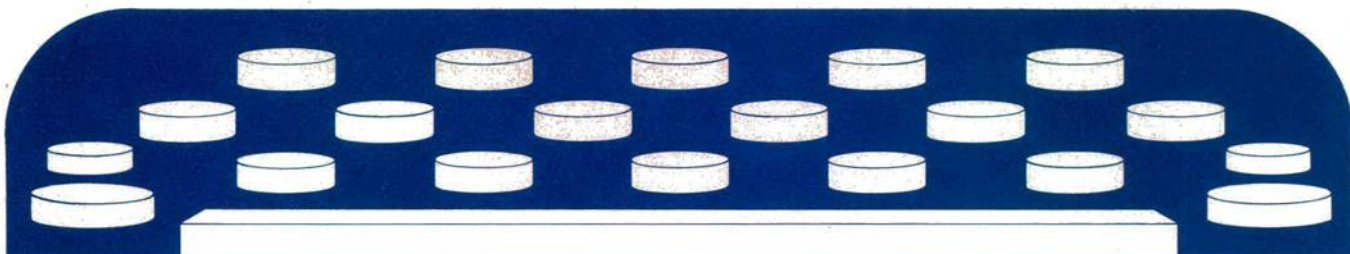
With new accurate measurements of the mass and density of the moons, their origin now seems clear. The density determined by perturbations of Viking during the February 1977 close approach suggests a composition similar to the carbonaceous chondrites — for example, the Orgueil meteorite and asteroids Ceres and Pallas. The light material is a "primitive" water-rich variant of the materials making up solid bodies in the solar system, and can only have formed beyond the orbit of Mars in the asteroid belt, since solar heat would evaporate the water from the forming materials any closer to the sun.

Prof. M. Woolfson of York University in England summarized theories of the origin of the Mars satellites in the light of this evidence. He was firmly in favor of the view that these essentially asteroidal objects were captured by Mars when they collided with one another in Mars' gravitational "sphere of influence". In such a situation, the asteroids lose enough energy for capture — and the theory has the merit that it produced both moons by one event. Other theories seem intrinsically less plausible, requiring an implausible capture sequence to be repeated for each moon!

As Veverka summed up, there are now at least two moons in the solar system whose origin has been tentatively determined. But we are still left with the puzzle of the origin of all the others, including our own. ☛

Space 1978...

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IN FOCUS

Sir / The first and foremost problem in observing is light. As the fifth largest city in the nation, Houston's night sky is awful, to say the least. I live in the busiest and most densely populated area of town. One block from my house lies the city's largest shopping mall, about three blocks away an AMC dealership, four blocks away a large Ford dealership, and a half mile straight west is the city's largest shopping center (as far as land area.) It's spread out all over the place! Also near me are hundreds of stores, thousands of homes, and seemingly millions of cars! All of that causes a light pollution problem you simply wouldn't believe. Of course, we have regular air pollution, too.

Another problem we have constantly is poor transparency and high atmospheric tremor. Had Antoniadi lived here, he probably would have started his seeing scale with five, had he not given astronomy up all together. Houston is quite frequently smothered in a thick blanket of clouds, as is all of the Gulf Coast. The clouds *never* fail on nights of the best meteor showers, and we can't see the dim ones because of all the light pollution. M-31 is almost completely washed out in a 2.4 inch refractor; with a lot of imagination, you can just barely make it out, even when it's near the meridian. Even bright little NGC-2287 is inordinately hard to see in 7x50 binoculars. And those are only two of the celestial wonders spoiled for us in Houston. If nothing else, in the summer, mosquitos swarm like hornets and eat you alive unless you're covered from head to toe in bug repellent. And whatever the sky looks like, it's hard to enjoy it with all the noise of racing cars, screeching tires, and general big city sounds.

How do I deal with all the light pollution and everything else? I don't. How can I? I'd have to drive 75 miles at least to get away from Houston's influence.

J.M. BUEHRING
Houston, Tx.

Sir / Living in the south suburbs of Chicago, light pollution is a constant

observing and photographic problem. Only on clear crisp nights are stars below 4-1/2 magnitude visible in my area.

I do have the advantage of packing up my astronomical gear and driving out to a forest preserve in my area. However, many times I prefer to stay in my own backyard and *try* to photograph the stars — without much success, I must add.

Due to the bright sky in all directions except to the south, my astrophotos are constantly being washed out. I have found, though, that short exposures produce better pictures on most objects.

DAVID GODIN
Midlothian, Ill.

Sir / Living as I do in one of the world's most inappropriate locations for deep sky photography, I've become a reluctant specialist in light pollution. In Manhasset, N.Y., I'm about 15 miles east of Manhattan and three miles east of the city line — about where the "finger" of Long Island disappears into the blob of light that is New York City.

My neighbors have a fondness for 2,000 watt porch lights, garage lights, driveway lights, path lights and floodlights! In another six years the junipers I've planted around the perimeter of the yard should be big enough to block out a good deal of this glare, but in the meantime I've got to live with it.

Frankly, the best way to deal with light pollution is to acquire in-laws living in remote areas who do not mind if their eccentric son-in-law spends half the night crouched over his paraphernalia in the backyard. My best deep sky photographs have come from such metropolises as North Sandwich, N.H. and Naco, Ariz.

There are two other things I've found helpful. In my area, the sky to the north and east, away from the city, has proved *considerably darker* than the sky to the south and west, even though it *does not appear so* to the eye! If you're shooting from the suburbs, I'd recommend concentrating on objects in a portion of the sky away from the city. Also, a rubber eyeguard (such as that offered in the

Edmund Scientific catalog), attached to the eyepiece, can shield your eye from your neighbors' searchlights and headlights, reducing exasperation and allowing your eye to become more dark adapted.

DAVID HEALY
Manhasset, N.Y.

Sir / I live in Paterson, N.J., approximately 15 miles west of New York City, so light pollution poses a significant problem. The introduction of mercury vapor lamps about a dozen years ago has considerably worsened conditions, to the extent that observation of any diffuse object over seventh magnitude is severely hampered. For example, in 1962 I could view a 10th magnitude galaxy with a 2.4 inch refractor. Now, on most nights, they appear equally faint — but only with the aid of a telescope nearly four times as large! With any instrument of smaller aperture, they would probably be undetected. On the other hand, 50 miles west of the area, the dark sky transforms the Whirlpool nebula in Canes Venatici from a diffuse double blob into a magnificent object with a bright nucleus and granulated spiral arms. The same skies clearly show the Horsehead nebula in Orion with a six inch telescope.

In my opinion, an astronomy enthusiast cannot solve the problem of light pollution unless he packs his telescope into a car to escape its effects. At the rate things are going, anyone with an appreciation of the beauty of the night sky may soon be doing all observing from an island where all lights except red-covered flashlights will be banned.

Perhaps such exotic alternatives as this will behoove the entire astronomical community to conduct a campaign against light pollution — but this would require a united front comprised of professionals, amateurs, planetarium educators, the Astronomical League, manufacturers of astronomical instruments, and the publishers of astronomically-oriented periodicals such as *ASTRONOMY*. It is the only way to combat such a formidable foe.

RICK KURCZEWSKI
Paterson, N.J.

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STAR DOME

SEPTEMBER

by

James Mullaney and Henry J. Phillips

Learning the names of the individual stars is both entertaining and absorbing. It's fun to roll those mellifluous Arabian words off the tongue and intriguing to learn what the names signify — anything from the mysterious title "The Solitary One" (Alphard) to the disconcertingly prosaic "Armpit of the Giant" (Betelgeuse)!

It's usually only the brightest stars, however, that carry such titles. Once you've learned the names of the most luminous stars, it's easy to flounder around with the fainter ones. But there must be an easier way to refer to a star than by stumbling ("That medium-bright star halfway between Deneb and Albireo — not quite in the center, but fairly close; let me look up its name — I'm afraid it hasn't got one!"). After a while, you might feel like you're running panicked through the wood where things have no names (in Lewis Carroll's *Through the Looking-Glass*).

Fortunately, a system does exist — one quite simple to use, and which can help you unmistakably identify not only a star, but the constellation in which it is located. (There is, after all, nothing in the word "Vega" which indicates that

you find it in Lyra.) The stars in each constellation are identified by the letters of the Greek alphabet (a complete listing can be found in the table on this page).

Most of us are aware that our constellation names are based on those of the Greeks, and the myths and legends that we usually read about are Greek ones. So does that mean that it was the Greeks who initiated this handy system? Not at all! As a matter of fact, the practice didn't begin until 1603, when Johann Bayer [in his *Uranometria* (a map and an atlas we've encountered before in *Star Dome*)], designated the stars on each of his charts with Greek letters. Other astronomers and cartographers had previously attempted to institute similar systems, but Bayer's was the one that "took hold".

It works this way: A star that has been assigned a Greek letter is called by that letter, plus the genitive form of the name of the constellation in which it is located. Thus, for example, we have Alpha (α) Cygni, Beta (β) Lyrae, Gamma (γ) Serpentis, and Delta (δ) Geminorum, situated (respectively) in Cygnus, Lyra, Serpens, and Gemini. Different

constellation names form the genitive in various ways, but it's always easy to recognize the original title.

One more point must be made about the Greek letter system, and it's one that has inspired a great many misconceptions. You'll find in virtually any astronomy book you care to open the statement that, "The stars in each constellation are designated by the letters

The Greek Alphabet

Alpha (α)	Nu (ν)
Beta (β)	Xi (ξ)
Gamma (γ)	Omicron ($\omicron$)
Delta (δ)	Pi (π)
Epsilon (ϵ)	Rho (ρ)
Zeta (ζ)	Sigma (σ)
Eta (η)	Tau (τ)
Theta (θ)	Upsilon (υ)
Iota (ι)	Phi (ϕ)
Kappa (κ)	Chi (χ)
Lambda (λ)	Psi (ψ)
Mu (μ)	Omega (ω)

This Star Dome rendering approximates the sky as it appears at about 11:30 p.m. Local Daylight Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 52.





of the Greek alphabet in order of brightness."

Well, as with most blanket statements, "It ain't necessarily so!" True, most constellations have one star that is obviously the brightest and can safely be called Alpha. Several constellations are lucky enough to have other stars that can be labeled Beta, Gamma, and Delta in descending order of brightness. But you will search in vain for a constellation that successfully carries the whole system through all the way to Omega. In fact, there is not one single constellation in which the stars with Greek letter titles are arranged in strict order of brightness!

A more reasonable statement to make would be: "The brighter stars in a constellation have designations near the beginning of the Greek alphabet, while the fainter ones are farther down the list." This is certainly more accurate (and much safer), but even *this* rule breaks down for some groups. For example, Alpha and Beta Sagittarii are so much fainter than a good many of the other stars in Sagittarius — including all those in the teapot asterism — that you'll probably shake your head in puzzlement at Bayer's Greek letter applications. Don't be too hard on Bayer, though; he (as most other astronomers of his time) was following the authority of Ptolemy, who assigned star magnitudes in the second century A.D. (and who has a reputation as a "sloppy" worker). (See the January 1977 *Star Dome* for more details about Bayer's working methods.)

There are a couple more stumbling blocks on the road to Greek letter clarity. Some constellations — the smaller ones — have only a few stars so designated; a few (like *Lynx*) must content themselves with no more than an Alpha. Also, you'll sometimes find more than one star in a constellation identified by the same Greek letter. In *Cygnus*, for example, there are two stars labeled Nu, two called Omicron, two called Pi, and two titled Omega. (Stars with the same letter are usually found close together, but they're not always identical in brightness.) This doubling-up process approaches the ridiculous in some places: *Orion* has six stars labeled Pi, and *Eridanus* has nine designated Tau! In such cases, the stars are called Pi 1, Pi 2, and so on.

Let's take a look at one constellation to see how the system works; we'll use *Capricornus*, this month's Close-Up region, as our example.

Most of the stars in *Capricornus* are faint; it has no outstandingly bright members. For this reason, it's perhaps natural that the title "Alpha *Capricorni*" could not be applied to the "correct" star; the brightest star in *Capricornus* is Delta, at magnitude 2.98.

Second is Beta (magnitude 3.25), and third is Alpha 2 — for *Capricornus* has two stars close together that are collectively called Alpha. Alpha 2's magnitude is 3.77, while Gamma (fourth brightest) is at 3.80. One other star in *Capricornus* is brighter than magnitude 4.0: This is Zeta, which shines at 3.86.

The rest of the Greek-letter-bearing stars in *Capricornus* run in order of brightness as follows: Theta, Omega, Psi, Iota, Alpha 1, Epsilon, Kappa, Nu, Eta, Rho, Mu, Pi, Chi, Tau, Upsilon, Phi, Lambda, Sigma, Xi and Omicron. Compare this list with the table on page 73; it's easy to see that the stars don't follow the Greek alphabet in order of brightness. What's more, there are two stars in *Capricornus* that don't have Greek letters at all, but are brighter than at least 1/3 of those that do! These two are 24 and 36 *Capricorni*; the numbers that they bear are *Flamsteed numbers* — a completely different system of star nomenclature (we'll discuss it in a future installment of *Star Dome*).

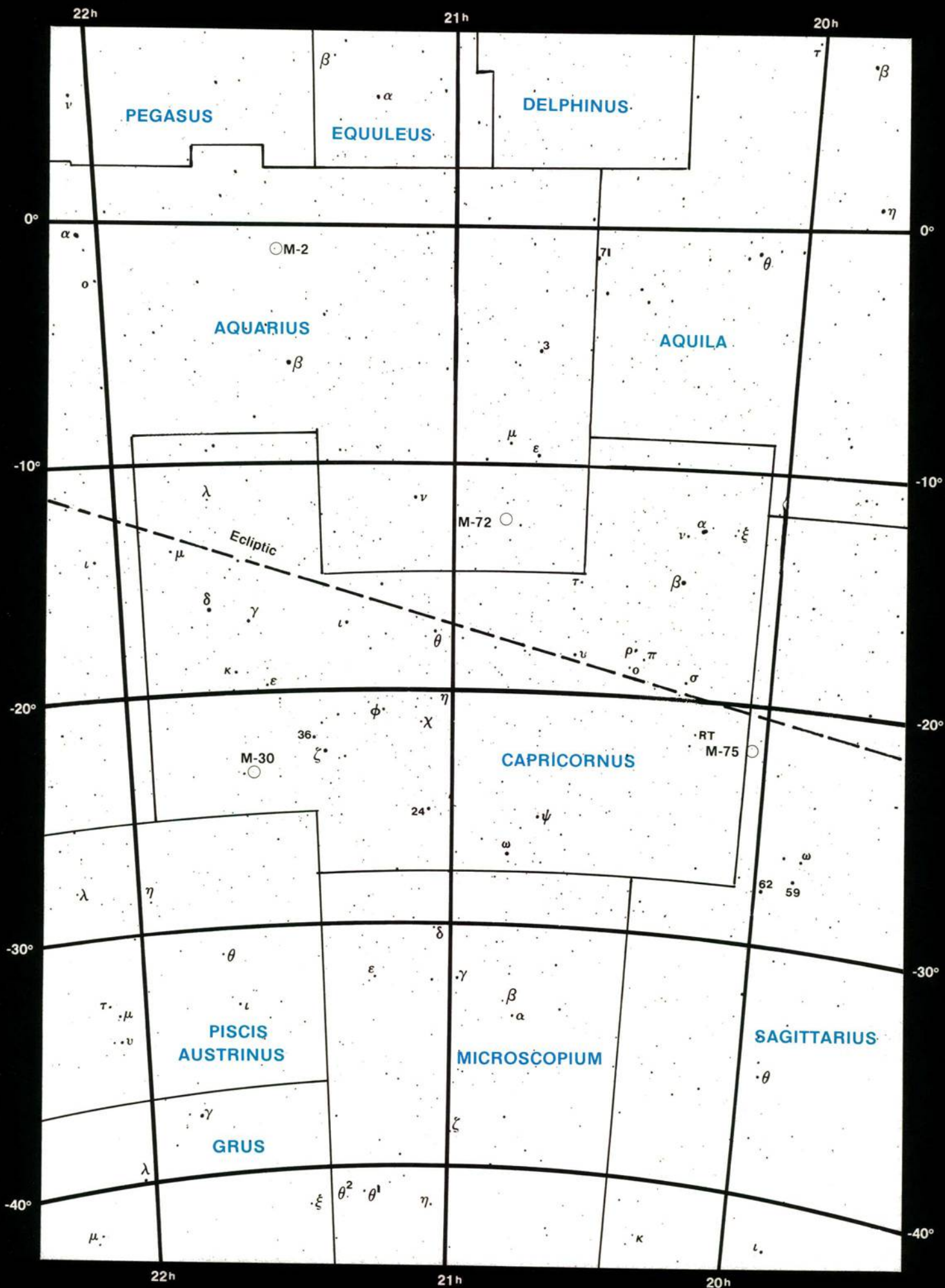
In the meantime, a few of the stars in *Capricornus* do have names that, while perhaps unsatisfactory to lovers of system, are beautiful and certainly worth repeating. Alpha 1 and 2 together are named Giedi, which means the goat (the animal that *Capricornus* represents); Beta is Dabih, from the Arabian *Al Sa'd al Dhabih* (the lucky one of the slaughterers — referring to sacrifices offered by the ancient Arabs at the constellation's rise). Gamma's name is Nashira, the fortunate one, while Delta is Deneb Algedi, the tail of the goat. Do you prefer the Greek designations or the Arabian words? The choice is yours!

Close-Up

Capricornus Region

During the summer months in *Star Dome*, we've explored several rich areas along the Milky Way, all jam-packed with telescopic treasures. Now, for those skywatchers who prefer more relaxed gem hunting in less crowded fields, a welcome change of pace is in store this month as we survey the "quiet" *Capricornus* region.

This zodiacal constellation — among the dimmest of the 12 — lies southeast of *Aquila's* first magnitude star Altair, beneath *Aquarius*, and ranks an unpretentious 40th in size among the constellations. As Barns pointed out in his *1001 Celestial Wonders*, *Capricornus* "offers few highlights aside from its two superb doubles, recorded in ancient writ, and at least one surpassing cluster." (These three objects are Alpha, Beta and M-30, all described in detail below.) This paucity of showpieces, combined with lengthening autumn evenings,



makes for leisurely sessions of contemplative observation.

Although regarded as a kind of stellar byway, Capricornus lies on the ecliptic and at times hosts various members of the solar system. Mars, for example, was located here during its close opposition in 1971. Capricornus' tranquil aspect has on occasion been strikingly disrupted, as in 2449 B.C.

when Chinese astronomers recorded a conjunction of all five bright naked eye planets here!

Alpha (α) Capricorni

In *Celestial Objects for Common Telescopes*, Webb remarked that even though this month's region is inconspicuous to the eye, it does contain "some good objects, among which its principal star takes a high rank". This "principal star" is the stunning naked eye duo formed by Alpha 1 and Alpha 2 Capricorni — a visual delight that's sure to attract your attention when you face south on clear dark September nights.

Alpha 1 shines near fifth magnitude, and Alpha 2 about fourth; the two suns are separated by an apparent angular distance of 375 seconds — more than six minutes of arc — in a roughly east-west direction in the sky. They have an unmistakable yellowish-orange cast (their spectral types are G5 and G8, respectively). Together they are a superb sight in binoculars and low power telescopes.

But this is not the system's sole attraction: Alpha is an apparent double-double system as seen in the telescope! Alpha 1 has a ninth magnitude companion 46 seconds distant near position angle 221 degrees, while Alpha 2's com-

panion shines at magnitude 10.6, seven seconds away at 158 degrees. Both attendants are within easy reach of a small telescope on a good night; the scene is similar to that shown in our drawing made with a four inch reflector at 35 power. The ninth magnitude star is considered an optical (unrelated) companion to Alpha 1, but the fainter one forms an actual physical binary with its primary, Alpha 2.

For observers using medium to large instruments, there is still more to be seen here. The 10.6 magnitude object is actually a close binary system itself, consisting of a pair of 11th magnitude stars about one second apart. This tiny combo makes Alpha 2 a triple rather than a double! Seeing it as such is considered a test for a six inch aperture scope, and requires both good seeing (image steadiness) and transparency (atmospheric clarity) for a clean split.

Webb called Alpha a "noble pair, obvious to naked eye", and gave their colors as both yellow. He noted that Alpha 2 has a companion, but said nothing of Alpha 1 having one. Likewise, Barns called this object "magnificent!" but made no mention of attendants. Even many modern observers seem unaware of Alpha's status as an apparent multiple system. Fortunately, Olcott (in his *Field Book of the Skies*) set the record straight, listing Alpha as a "Telescopic double-double. Both yellow."

Those who are already familiar with this unusual object have probably made the natural assumption that Alpha 1 and Alpha 2 are physically associated since they are so similar in brightness and color, and are so close to each other in the sky. Yet, the remarkable fact is that these two suns are totally unrelated! Not only are these objects moving through space in different directions, but they lie at vastly different distances from us. Their parallaxes indicate that Alpha 2 is relatively nearby — about 100 light-years away — but that Alpha 1 lies perhaps 10 times as far away in space. The reason they look alike is that the nearer star is a giant sun and the farther one a supergiant. Our view of them in our sky is the result of an incredible cosmic coincidence!

Alpha Capricorni may not be quite the show object that Epsilon (ε) Lyrae (the famed "double-double") is, but it has a strange charm all its own. This golden duo with tiny attendants grows on you the more you look at it, and seasoned double star enthusiasts seldom fail to view it whenever it's above the horizon.

Beta (β) Capricorni

Just two degrees south and east of Alpha is another fine, wide double star, well-suited for low power viewing. This is Beta Capricorni, and like its neighbor it appears to be only an optical

Alpha Capricorni



35x

Beta Capricorni



30x

Top: Alpha Capricorni — a double system detectable by the unaided eye — is revealed to be a "double-double" through the telescope. Each fairly bright orange member has a faint companion; the two pairs are separated by more than six minutes of arc. Our drawing, which has a field of view of 1.5 degrees, was made from a four inch reflector at 35 power. Bottom: Beta Capricorni is a wide, color contrasting double with gold and blue components (the gold being much the brighter of the two). This pair can be split with binoculars; if the two stars had a smaller separation, it would be one of the most beautiful binaries in the sky. This drawing was made from a three inch refractor at 30 power; the field of view is two degrees. Drawings by James Mullaney.

Selected Objects — Capricornus Region

Object	Type	Mag.	Size/Sep.	R.A. (1950)	Dec.
CAPRICORNUS					
RT Capricorni	V:393	6.4-8.1	—	20 ^h 14 ^m	-21° 29'
*α ¹ (Alpha 1)+	★2	4.6,9.0	46"	20 ^h 15 ^m	-12° 40'
*α ² (Alpha 2)+	★2	3.8,10.6	7"	20 ^h 15 ^m	-12° 42'
*β (Beta)	★2	3.25,6.0	205"	20 ^h 18 ^m	-14° 56'
π (Pi)	★2	5.2,7.5	3"	20 ^h 24 ^m	-18° 23'
ο (Omicron)	★2	6.1,6.6	22"	20 ^h 27 ^m	-18° 45'
* M-30	GC	8.4	6'	21 ^h 38 ^m	-23° 25'
SAGITTARIUS					
* M-75	GC	8.0	2'	20 ^h 03 ^m	-22° 04'

*Detailed in Close-Up
+Pairs separated by 375" (6')

★ 2 = Double Star
V:#d = Variable Star, period (days)
GC = Globular Cluster

Mag. = Magnitude
Sep. = Separation

pair — the chance alignment of unrelated suns going their separate ways.

The components here are magnitudes 2.5 and 6.0, and are about 205 seconds of arc apart in the sky — again in an east-west direction. This object is a fine sight in binoculars and small telescopes, as our drawing with a three inch refractor at 30 power indicates.

A definite color contrast between the two stars is evident even at a glance. The primary looks orange or deep yellow, agreeing well with its spectral class of K0, while the companion has a clear blue cast to it. If the components were only 1/10 as far apart as they actually are, Beta Capricorni would surely rival Albireo in Cygnus! As it is, most observers pay little attention to this object, regarding it as too wide at normal telescope magnifications.

This pair is absent from many of the classic lists but Webb dutifully recorded it, calling the stars yellow and blue, and commenting "very fine large field". Smyth also was not negligent; he saw the colors as orangish-yellow and sky blue — and so they look today.

Beta itself is a highly complex object consisting of at least three separate suns in orbit about a common center of gravity. Two unseen spectroscopic companions having periods of about nine days and four years lie within its warm glow. The entire system is some 130 light-years from us.

We pause to wonder at the occurrence of two rare — yet prominent — optical doubles like Alpha and Beta Capricorni, being found so close together in this part of the sky — almost as if arranged for our observing pleasure in this somber region! As Freeman Dyson recently put it, "... it almost seems as if the universe must in some sense have known that we were coming."

Why not check out these colorful duos the next clear night and let them know you're here!

M-75

Before leaving the western part of Capricornus, let's make a brief excursion just over the border into neighboring Sagittarius to view a neglected globular cluster from Messier's list. This is M-75, found by sweeping with a low power eyepiece roughly midway along a line joining Beta Capricorni and a naked eye grouping of four stars that includes 59, 60, 62 and Omega (ω) Sagittarii.

This little cluster glistens near eighth magnitude and measures just two minutes across. Although small for a globular, it is well worth the time to locate. In addition to its distinction as a Messier object, M-75 happens to be one of the most compressed members of its class to be found anywhere in the sky. Globular concentration is often rated on a scale from I (highest) to XII

(lowest). M-75 is given as type I, making it even more tightly packed than well-known M-80 (see Star Dome, July 1977), which is considered type II.

Even a small telescope will show M-75 as a hazy patch with a bright core, but at its distance of nearly 80,000 light-years, this object challenges the capabilities of the largest nonprofessional instruments in resolving its individual stars.

This cluster has been overlooked by many observers, both past and present. Perhaps this is due to its border position, far removed from the greater glories of the Sagittarius starclouds to the west. Even when visited, M-75 reveals its true nature only grudgingly — keeping its privacy by distance like some cosmic recluse!

M-30

We conclude our survey of this month's region by turning our attention now to eastern Capricornus and that "surpassing cluster" mentioned earlier by Barns. Here we find another globular cloud of stars; this one is M-30. A finder will show it on a dark night situated about seven degrees south of Delta Capricorni or three degrees southeast of Zeta (ζ), very near the fifth magnitude star 41 Capricorni.

M-30 is listed in catalogs as being six minutes of arc in apparent size and shining at magnitude 8.4. Some sources, however, consider this object to be at least a magnitude brighter than this latter figure suggests. That this may well be true is indicated by a remarkable fact brought out in Barns' description of the cluster: "A fairly luminous naked eye aggregation of ± 12 th magnitude stars, recorded by Aratus and other classic historian-observers." Here is another sign that ancient stargazers enjoyed much more transparent skies than their modern counterparts. Truly a tragic consequence of contemporary civilization is our increasing loss of the night sky, especially near large cities.

At its low southerly declination of $-23\frac{1}{2}$ degrees, M-30 certainly looks at least as faint as eighth magnitude. In three and four inch scopes, it appears as a small spherical nebulosity with central condensation. One modern observer states that no hint of resolution is evident in a six inch reflector at 300 power, but Olcott wrote that this beehive could be broken into stars in a five inch refractor. On a good night, even a three inch instrument shows a granular texture to this cluster — the precursor of actual resolution.

Bernhard, Bennett and Rice (in their *New Handbook of the Heavens*) described M-30 as follows: "Pale white and fairly bright; elliptical, with a 'central blaze'; forms a nice contrast with a star beside it. Resolvable into stars, with medium apertures." Webb's

impression was similar: "Moderately bright; beautifully contrasted with an eighth magnitude star beside it; comet-like with 64 (power); with higher powers resolvable." This observation was made with a 3.7 inch refractor from the latitude of the British Isles.

As with other globular clusters, Lord Rosse noted the spiral arrangement of M-30's outer star streams with his large metal mirrored reflectors; this is visible in a modern 10 or 12 inch scope at high power on a good night. The *New General Catalogue* considers this object "remarkable" — and so it is, compared with the vast number of faint clusters and nebulae which this classic work contains.

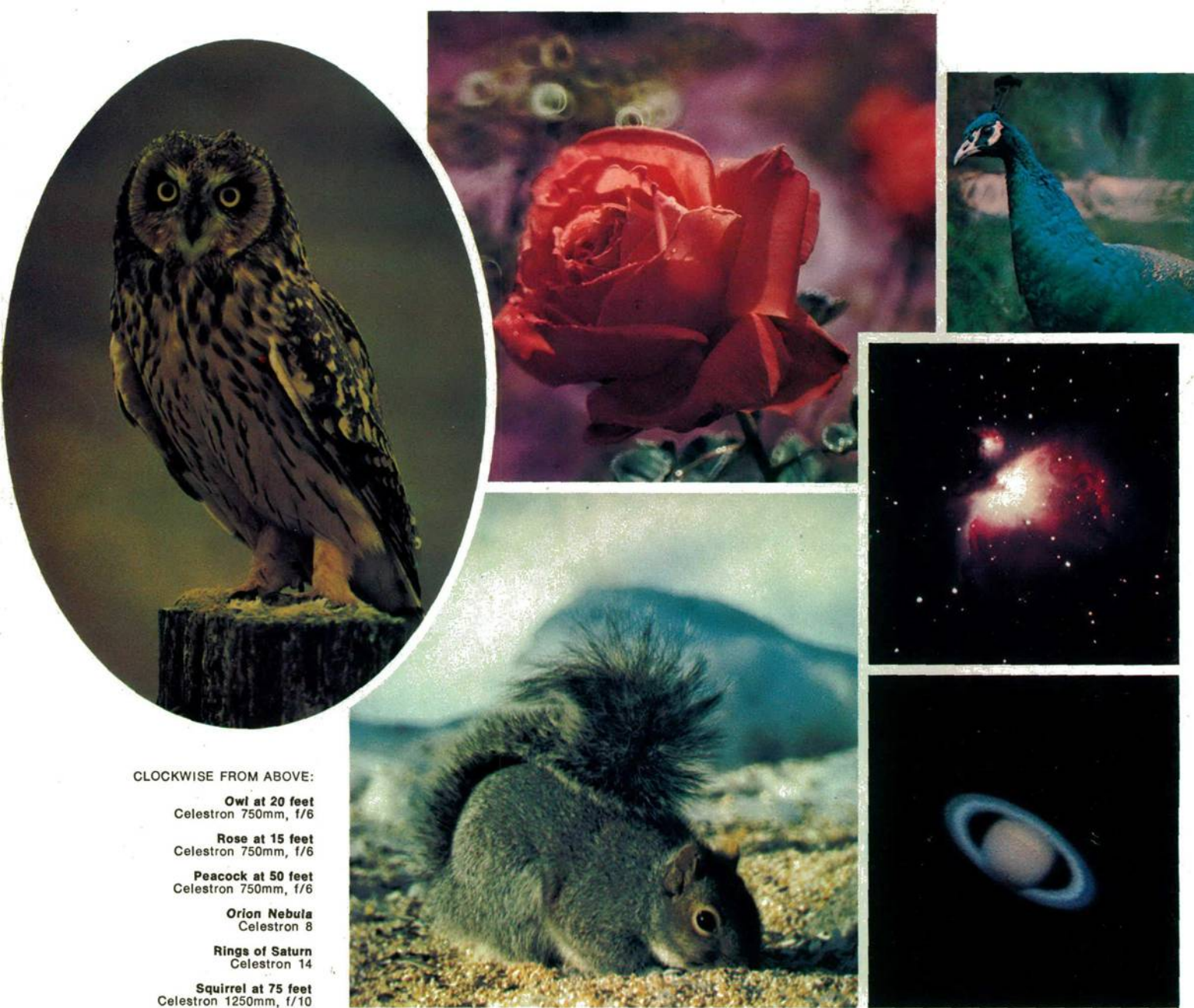
Without question the most inspired account of M-30 is that given by Smyth, as seen through his six inch refractor: "What an immensity of space is indicated! Can such an arrangement be intended, as a bungling spouter of the hour insists, for a mere appendage to the speck of a world on which we dwell, to soften the darkness of its petty midnight? This is impeaching the intelligence of Infinite Wisdom and Power, in adapting such grand means to so disproportionate an end. No imagination can fill up the picture, of which the visual organs afford the dim outline...."

It is such lofty insight and expression as this — inspired by direct visual observation of the heavens with our own eyes — that constitutes the greatest and yet least suspected benefit of stargazing. As you contemplate M-30's softly glowing swarm of suns from across more than 40,000 light-years of interstellar space, what elevated thoughts enter your mind? Who or what is their source?

Many are now beginning to suspect that our minds somehow hold the key to bridging such vast gulfs of infinity as that separating us from objects like M-30 — some undiscovered direct link between man and cosmos. They agree with Sir James Jeans who wrote: "... for surely there must be some more direct contact than that light can travel between them and us in a hundred million years?"

How this quest for ultimate contact with the universe may come about is suggested by the crowning thought of Richard Bach's *Jonathan Livingston Seagull*: "You will begin to touch heaven, Jonathan, in the moment that you touch perfect speed. And that isn't flying a thousand miles an hour, or a million, or flying at the speed of light. Because any number is a limit, and perfection doesn't have limits. Perfect speed, my son, is being there."

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CLOCKWISE FROM ABOVE:

Owl at 20 feet
Celestron 750mm, f/6

Rose at 15 feet
Celestron 750mm, f/6

Peacock at 50 feet
Celestron 750mm, f/6

Orion Nebula
Celestron 8

Rings of Saturn
Celestron 14

Squirrel at 75 feet
Celestron 1250mm, f/10

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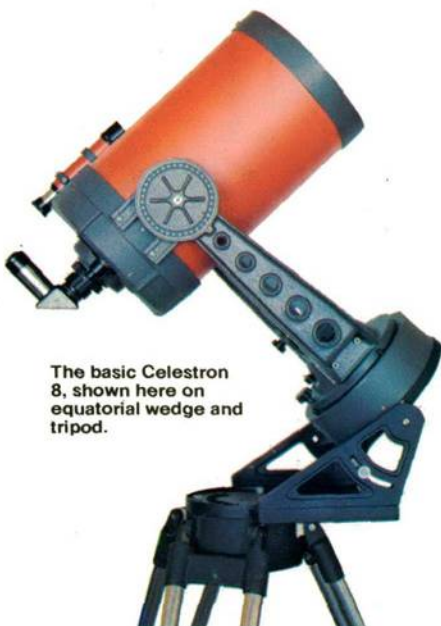
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